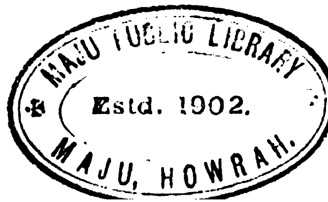


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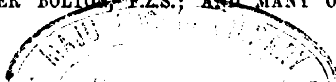
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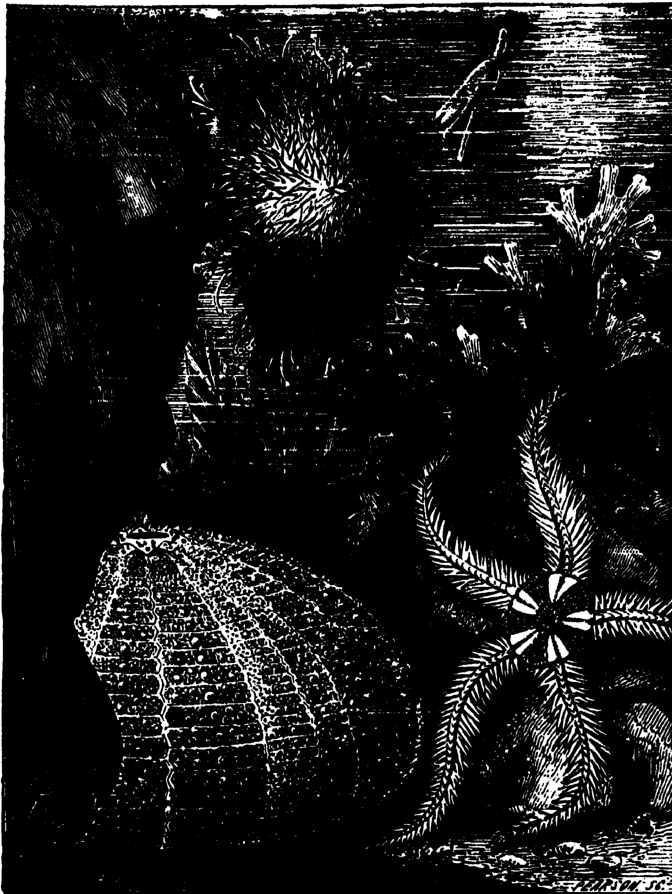
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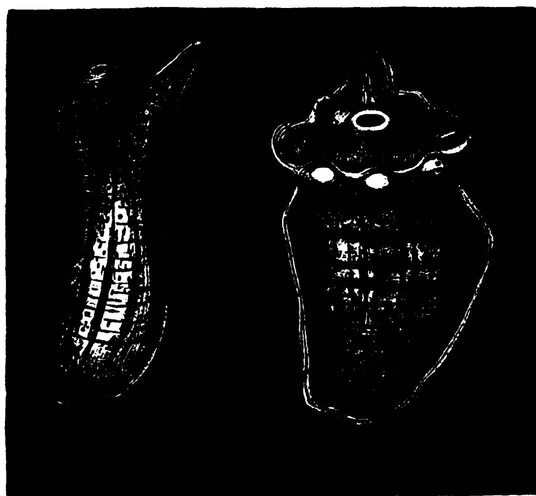
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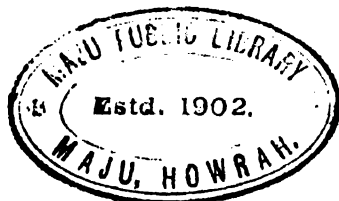
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GIANT SWIFT MOTH



THE ROYAL NATURAL HISTORY.



INVERTEBRATE ANIMALS.

CHAPTER I.

The Jointed Animals,—Subkingdom **ARTHROPODA.**

The Insects,—Class **Insecta.**

Ants, Wasps, Bees, etc.,—Order Hymenoptera.

Distinction between Vertebrates and Invertebrates.

In the early days of zoological science, when the value in classification of the structural and embryological characters of living beings was but little understood, the animal kingdom was divided into two subkingdoms called Vertebrata and Invertebrata; the former embracing those forms provided with a vertebral column, or backbone, and the latter those that were not so provided. With the addition of some few classes, whose organisation has only recently been fully comprehended, the Chordata of to-day are coextensive with the Vertebrata of half a century ago. But the term Invertebrata, as denoting a natural assemblage of animals, has long ceased to be used by every competent zoologist, and is nowadays merely applied as a conveniently vague title for all the animals that have not acquired the characters of the Chordata. This change of opinion has been brought about by the attainment of a far more intimate acquaintance with the structure and development of the lower animals than our predecessors, with their less refined methods of investigation, could possibly

possess; and it has resulted in the splitting up of the so-called invertebrates into a number of subkingdoms, each of which is equivalent to the entire group of Chordata.

It must not, however, be supposed that no advance has been made of late years in chordate morphology, and that the conception of the essential characters of the group is the same as it was in the earlier part of the century. So far indeed is this from being the case, that the zoologists of those days would certainly be greatly puzzled to understand the reasons for the present wide extension of the group to embrace such forms as the sea-squirts and the worm-like *Balanoglossus*, which have no vertebral column, and do not even present the outward semblance of any of the classes of the true Vertebrata. Strictly speaking, therefore, they are not Vertebrates at all; yet their claim to be ranked in the same great category of animals as the lancelet, which also has no backbone, and the fishes, is now generally accepted, and is based in the main upon their possession, in common with all the true Vertebrates, of three characteristics not found in any other group of the animal kingdom. These are, firstly, the presence of slits in the lateral walls of the pharynx, by means of which the anterior part of the alimentary canal is put into communication either with the body-cavity or directly with the outer world; secondly, the existence, either as a temporary or permanent structure, of a cartilaginous rod, the *notochord*, lying lengthwise in the upper part of the body; and, thirdly, the position of the principal nervous tract, also in the upper part of the body, but above the notochord. The fate of the notochord in the different classes of Chordates is somewhat varied. In some of the sea-squirts, for instance, it persists only in the tail, which may entirely disappear when the animal settles down to its sedentary life. Hence these creatures are sometimes called the Urochordata, or rod-tailed. In the lancelet, however, this structure remains throughout life, and extends from the end of the tail to the extremity of the head. Hence the section containing this little fish-like creature is called Cephalochordata, or rod-headed. In all the higher members of the assemblage, however, that is to say, in fishes, amphibians, reptiles, birds, and mammals, the notochord falls short of the front end of the head, terminating just behind a point which in the floor of the skull eventually becomes the pituitary fossa. Moreover, in all the forms that acquire a bony skeleton, this rod is to a greater or less extent replaced by the bodies, or *centra* of the vertebræ, or segments composing the backbone; these centra supporting the bony arches developed for the protection of the dorsal nerve-chord. No less varied is the fate of the pharyngeal slits, or visceral clefts. Whereas in the lower Vertebrata, such as fishes, these remain as the branchial slits, in the adults of the more highly organised forms, like mammals, they practically disappear, one only remaining as the eustachian tube, by means of which the back of the mouth communicates with the inner chamber of the ear.

With this brief résumé of the fundamental features of Chordate morphology, we may turn to the remaining groups of animals, the so-called Invertebrata, which, as a whole, may be distinguished from Chordates merely by negative characters, there being no pharyngeal slits, no notochord, and no central nervous system running along the back. Nevertheless, some of the higher groups of invertebrated animals—such as the Arthropods and Molluscs—resemble each other, and differ

from the Vertebrates in the arrangement of some of the principal organs of the body. For instance, although as in Chordates the front end of the nervous chord is lodged in the head above the mouth, and constitutes the brain, the rest of it runs along the ventral or lower surface of the body beneath and not above the alimentary canal, which thus, in its anterior or œsophageal part, passes right through a ring or collar of the nervous system. Again, the chief centre of the circulation, the heart, is lodged in the back and not in the lower part of the body, so that the arrangement of these two structures is exactly the opposite of that which obtains in the Chordata. If, for example, a transverse section be cut through a fish a little behind the head, the nerve-chord, the alimentary canal, and the heart will be found to occupy the following positions—the first named being in the back, the second in the middle, and the third below; while, on the contrary, a section of the same kind, taken in substantially the same place in a centipede, will show that the heart is above, and the nerve-chord below the alimentary canal.

This arrangement of the organs in question does not, however, exist in all invertebrated animals. In some the nervous system is absent; in others it consists of two strands, one running along each side of the body, and neither above nor below the alimentary canal. In others, again, there is no circulatory system, and in others no alimentary canal. There is consequently an extreme divergence in anatomical structure between various kinds of Invertebrates, and zoologists have attempted to express these differences, as explained above, by the referring these various creatures to distinct subkingdoms.

Eight of such subkingdoms are provisionally recognised in the present work, and are arranged as follows:—(1) Arthropoda, or Invertebrate animals with jointed legs, such as insects, spiders, and crustaceans; (2) Echinodermata, or star-fish, sea-urchins, stone-lilies, etc.; (3) Mollusca, or soft-bodied, unsegmented animals, often with a shell, but without legs, like cuttle-fish, whelks, and oysters; (4) Molluscoida, including the lamp-shells and corallines; (5) Vermes, or worms and their kindred; (6) Cœlenterata, or jelly-fish, sea-anemones, and corals; (7) Porifera, or sponges; and (8) Protozoa, or single-celled animals, like the microscopic foraminifera. As the special characters of each of these subkingdoms are pointed out in the chapters devoted to them, no further reference is necessary in this place.

Special Characters of Arthropods.

The term Arthropoda is applied to the classes of animals composing this subkingdom in allusion to the fact that the limbs are divided by joints into a series of movable segments. The title, however, is not in all respects satisfactory, seeing that members of other groups, mammals and birds for instance, also have jointed legs, and in one important though not typical class of Arthropoda, namely, the Prototracheata, containing the aberrant family *Peripatidæ,* the appendages are short and undivided. The name is consequently often superseded by the later but more appropriate term Gnathopoda, meaning foot-jawed, which refers to a characteristic that is perfectly distinctive of all the species included under the heading. This is the transformation into jaws, or *gnathites,* as they are sometimes called, of one or more pairs of the appendages that lie at the sides of the mouth, or just behind it. The number of pairs involved in the formation of jaws varies from one to six, the smallest being found in *Peripatus,* and the largest in crabs and their allies, while between these

two extremes we meet with two pairs in the Millipedes, three in the Insects, and four in the Centipedes.

The appendicular nature of the jaws, then, is the most distinctive feature of the animals now under discussion. But if two members of the Arthropoda, say for instance a lobster and a centipede, be compared together, they will be found to possess many other structural characters in common. Thus the body is bilaterally symmetrical, that is to say, if it be cut exactly in half lengthwise, the right and left portions will be precisely alike. It is, moreover, divided into a series of segments, placed one behind the other in a long series; each segment bearing a pair of limbs, which in the centipede are all alike, but in the lobster vary considerably in size and structure in different regions of the body. In both types, moreover, some of the segments at the front end of the body are modified by fusion, and in other ways, to form a head, which is furnished with eyes, and bears, in addition to the jaws, appendages that have been transformed into long, many-jointed feelers, called antennæ. In the lobster, however, there are two pairs of these organs, while in the centipede there is but one.

These external resemblances are correlated with others connected with the internal anatomy. The alimentary canal, for instance, traverses the body from end to end; and the nerve-chord lying beneath it consists of two adjacent strands united together in the separate segments, the points of union being marked by swellings called *ganglia*, from which nerve-threads radiate to the neighbouring parts. Above the alimentary canal comes the heart, and this organ, although superficially very different in the two types, is yet constructed upon the same general plan. In the centipede it is long, tubular, and composed of many distinct segmentally-arranged chambers, and furnished with arteries for the distribution of blood to the tissues, and with slits or *ostia* by which the fluid again makes its way back to that organ. In the lobster, on the contrary, the heart is short, thick, and consists of a single chamber, but is nevertheless provided with the arteries and slits as in the case of the centipede.

The dissection of these two creatures would, however, reveal one fundamental difference between them. In the centipede it would be noticed that the body is supplied internally with a rich system of branching tubes which open on the exterior by means of apertures placed in the sides of the segments. These tubes are known as *tracheæ*, and their apertures as *stigmata*. They, or similar structures, are found in nearly all Arthropods that live upon the land and breathe the oxygen in the air. They are, in fact, the breathing organs, and analogous to the lungs. The lobster has no such system of tubes; for living in the water, and breathing the oxygen dissolved therein, this crustacean has need of a different type of respiratory organ analogous to the gills of fishes. These it possesses in the form of delicate plumes attached to the bases of the walking-legs and the sides of the body just above them; and although concealed from view and protected from injury by a large plate, these gills are yet freely exposed to the water in which the animal spends its existence. Gills resembling those of the lobster in function, and also substantially in structure, are found in almost all Arthropods that live in the sea.

The characters that have been here briefly alluded to in the description of the

anatomy of the centipede and lobster will be found to be equally discernible, if other prominent types of Arthropoda be examined. Differences of course will be found to exist; but, on the whole, the plan of structure that has been sketched is true for all the classes. For instance, in all of them, except the Centipedes and Millipedes, there is a tendency in the more specialised members towards an increase in size of the limbs in the front half of the body, accompanied by a corresponding dwindling of those in the hinder part. Thus a crab and a spider walk upon four pairs of legs placed just behind the head, and an insect upon three; and in the case of the insect the legs of the hinder region have entirely disappeared, while the larger number of them have similarly vanished in the spider and the crab. There is also a tendency in the higher members of each class for the ganglia of the nervous chord to lose their segmental arrangement, and to become concentrated together in one large mass, placed near the seat of the greatest muscular activity. Nevertheless, underlying all the modifications of structure—however extensive these may be—there is a common plan of organisation which may be regarded as typical of the Arthropoda. This may be briefly sketched as follows. The long bilaterally-symmetrical body is divided into a series of approximately similar segments, each bearing a pair of similar and segmented limbs. These limbs are the organs of locomotion; but some of those at the front end of the body, where comes the mouth and the organs of vision, take on the function of jaws, and are used for seizing and masticating food instead of for progression. The nervous system consists of a double ventral chord with ganglionic enlargements in each segment, and the first ganglia of this ventral chain are connected by means of a chord on each side of the œsophagus with the brain, which is lodged in the head. The heart, lying above the alimentary canal—which runs from one end of the body to the other—consists of a series of chambers, one for each segment of the body, and is provided with arteries for the distribution of the blood, and with slits or ostia for receiving it back again.

The Arthropoda are divided into the following classes, the chief characteristics of which are described further on—(1) Insects (Insecta, or Hexapoda); (2) Centipedes (Chilopoda); (3) Millipedes (Diplopoda); (4) Spiders, Scorpions, Ticks, etc. (Arachnida); (5) King-crabs (Gigantostraca); (6) Crustaceans (Crustacea); (7) Prototracheata (*Peripatus*).

It is possible, however, to group these into larger divisions. The insects, centipedes, and millipedes, for example, may be placed together as Tracheata, characterised by the possession of tracheæ and of a single pair of antennæ. The Crustacea stand alone in having two pairs of antennæ, and in breathing with gills. By means, however, of the extinct class of the Trilobites, they are connected with the king-crabs; and these in possessing only six pairs of well-developed anterior limbs, and in having no antennæ, strikingly resemble the Arachnida. *Peripatus* is very peculiar, but shows signs of a distant relationship with the centipedes, although in many anatomical features it is not very far removed from the worms.

Distinctive Characteristics of Insects.

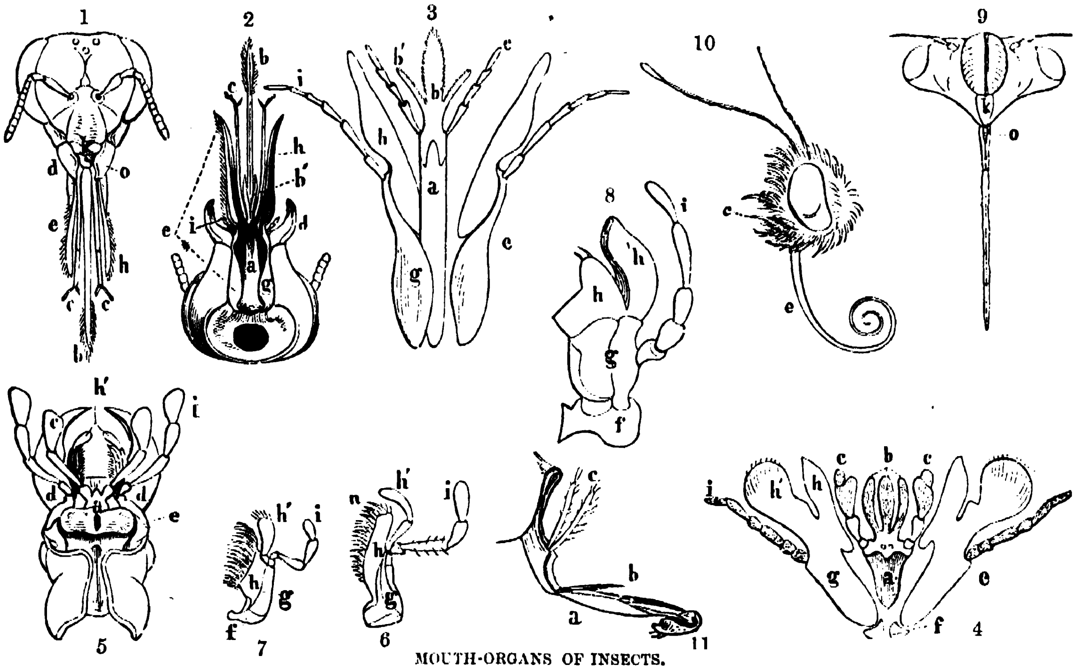
The term insect, although originally and, according to the meaning of the word, correctly employed in a wide sense to embrace all those animals in which the body is externally divided into a

number of segments, including, of course, butterflies, beetles, bugs, spiders, scorpions, centipedes, millipedes, not to mention crabs and shrimps, is now, by common consent, used in a much more restricted sense to apply solely to such members of the Arthropoda as have only six walking-legs. In allusion to this feature the class is nowadays often called the Hexapoda, the term being much more precise and applicable than that of Insecta. In addition, however, to the possession of six legs, insects are characterised by certain other well-marked features, serving to distinguish them from all other arthropods. The body is divided into three distinct regions, arranged in a longitudinal series, and named respectively, from before backwards, the head, thorax, and abdomen.

The head, which varies much in size and shape in different groups, bears the eyes, the antennæ, and the jaws. The eyes are of two kinds, simple and compound. The latter, of which there is a single pair, situated one on each side of the head, and often so large as to occupy the greater part of its right and left half, consist externally of a multitude of lenses, often exceeding many thousands in number. The simple eyes, or ocelli, on the other hand, are fewer in number—usually only two or three—and placed upon the forepart of the head. The antennæ are movably articulated by means of a special socket to the front of the head, usually below or near the inner edge of the compound eyes. They vary much in structure and length, being sometimes long and pliable, and composed of a large number of segments, as in the cockroach, and at other times short, like those of the house-fly, and consisting of a few segments only. There is no doubt that the antennæ contain highly important organs of sense, the bristles with which they are studded being probably tactile, and some of the other organs possibly olfactory in function.

The front edge of the head, or its lower edge when carried vertically, is often movably jointed to the rest of it, and constitutes an upper lip, or labrum. In the formation of the jaws, which are attached to the lower surface of the head, three pairs of appendages, respectively named the mandibles, the maxillæ, and the labium, are involved. But these parts are susceptible of an extreme amount of variation in structure and function, being sometimes formed for mastication, as in the mandibulate forms, such as the cockroaches and beetles, and sometimes for piercing or sucking, or both combined, as in the so-called sucking forms like the flies, butterflies, and bugs. There is no doubt that the mandibulate type of mouth in which the gnathites, or jaws, are more foot-like in structure, is the most primitive of all. In this case the mandibles usually consist of a stout pair of one-jointed skeletal pieces, the inner edge of which is furnished with biting teeth. Sometimes, as in the males of stag-beetles, the mandibles are enormously large, and simulate horns. The maxillæ are much more complicated in structure; each consists of a basal piece, composed of two segments—the cardo and stipes—from which spring two branches, an outer or palp, which has the appearance of a dwarfed limb, and an inner, which is in its turn double, the inner blade being called the lacinia, and the outer the galea. The jaws of the third pair, constituting the so called labium, or lower lip, are constructed upon the same principle as the maxillæ, but the parts usually considered to correspond to the cardo are united to form a plate—the mentum—which is articulated by its hinder part to a sternal plate of the head, called the submentum. In front of the mentum there are

externally the jointed palpi, resembling those of the maxillæ, and between these there is a median, sometimes bilobed, piece, called the ligula, and a pair of pieces termed the paraglossæ. The degree of development of the several parts varies greatly in different orders, and it is often a matter of considerable difficulty to determine the exact correspondence that exists between them in two insects belonging to different orders. This is especially the case when the jaws have been modified to form the different organs of suction that are met with. The structure of these will be described in detail when the species that possess them are discussed. Another organ to be mentioned in connection with the jaws is a



MOUTH-ORGANS OF INSECTS.

1, Head of honey-bee, from the front; 2, Head of humble-bee, from below; 3, Maxillæ and labrum of a bee (*Andrena*); 4, Maxillæ and labium of saw-fly (*Cimbex*); 5, Lower view of head of carnivorous beetle (*Procrustes*); 6, Maxilla of carnivorous beetle (*Cicindela*); 7, Maxilla of cock-tail beetle (*Staphylinus*); 8, Maxilla of locust; 9, Head of bug (*Cicada*) from the front; 10, Head of butterfly; 11, Head of horse-fly (*Tachina*).

Labium—*a*, mentum; *b*, ligula; *b′*, paraglossæ; *c*, palp; *d*, mandible. *Maxilla* (*e*), with *f* cardo; *g*, stipes; *h*, lacinia; *h′*, galea; *i*, palp; *k*, head-plate; *n*, teeth on lacinia.

membranous lobe, called the hypopharynx, or tongue, projecting into the interior of the mouth from the floor of the labium.

The thorax, or median part of the insect's body, is formed of three segments called the pro- meso- and metathorax, each of which is composed of several distinct pieces. The dorsal areas of the three segments are termed the pronotum, mesonotum, and metanotum; the lateral regions the pleuræ; and the inferior regions the sterna. To the pleuræ are articulated the three pairs of legs, each of which consists primarily of five segments, named respectively, from the base to the apex, coxa, trochanter, femur, tibia, and tarsus; the last, which constitutes the foot, being generally tipped with two claws, and subdivided into several—often as many as five—smaller segments. To the sides of the upper surface of both the meso-

and metathorax are usually attached a pair of wings, which are very characteristic organs of all the higher insects, although absent in the lowest forms, and in many species degenerate through parasitic habits. The wings differ much in structure, thickness, clothing, etc., in different orders of insects, but in all cases they seem to consist of an upper and a lower membranous layer, traversed by narrow bands of thicker material, the nervures.

The abdomen in insects is marked off from the thorax by the absence of true appendages. It may consist of as many as ten distinct segments, but never of more, and generally of fewer. Each segment is protected above by a dorsal plate, or tergum, and below by a ventral plate, or sternum, the two being connected laterally by membrane. The last segment is often provided with a pair of appendicular structures, which may be long, many-jointed, and antenniform, or short and one-jointed, like the pincers of an earwig. And, in addition to these, certain other structures, such as the stings of bees and wasps, and the ovipositors of locusts and ichneumon flies, are frequently connected with the hinder segments of the abdomen. The only other external structures that need be mentioned here are the stigmata, or apertures, of the respiratory organs. These pierce the lateral surfaces of the thoracic and abdominal segments, and vary much in number, size, and form, being generally far more plainly seen in the larvæ than in the adults. There may be as many as eleven pairs, but usually the number falls short of this.

In exceptional cases, as in the plant-lice (*Aphidæ*) belonging to the order Hemiptera, and in certain parasitic flies of the group Pupipara, the young are born in an advanced stage of development, the eggs developing within the body of the parent without being first deposited. But in the vast majority of species the young make their first appearance in the world in the egg-stage.

Between the time of its escape from the egg-shell and the attainment of maturity, the young undergoes a succession of moults, or castings of the skin. In some cases the change of structure that an insect presents during the course of its growth is, comparatively speaking, trifling, the young being hatched in a condition in which in outward form it substantially resembles the parent in everything but size, and, in the case of species that bear wings in the adult, in the entire absence of these organs. A familiar instance of this method of growth is found in the cockroaches and grasshoppers, in which the young emerge from the egg as miniature and wingless copies of their parents.

In other cases, however, as in the flies (Diptera) and butterflies (Lepidoptera), an extraordinary change of form takes place during growth, the young upon hatching being so totally unlike the adult that no one unacquainted with the facts of insect development would suppose the two to belong to the same category of animals. In these two orders, as well as in some others, the new-born young has the appearance of a fleshy grub; and the grub-like condition is retained unchanged, except in size, until the time for the last moult approaches. It then undergoes a startling change of condition, and, losing its organs of sense and ceasing to feed, passes into a state of quiescence, during which the final changes in its organisation are more or less rapidly passed through, and the final moult sets free the mature insect, perfect in all its structural details.

The immature stages of insects that present a complicated development of

this kind are variously spoken of as grubs, maggots, caterpillars, or, more comprehensively, larvæ; while the quiescent stage is termed the chrysalis or pupa, and the final sexually mature stage the imago or perfect insect. Moreover, such species are said to undergo a complete metamorphosis, or to be holometabolous, as opposed to those like the cockroach, whose growth is accompanied by but little change of form, and are said to present an incomplete metamorphosis or to be ametabolous. It must not, however, be supposed that all insects are either completely or incompletely metamorphic in their development. The familiar types that we have mentioned exhibit almost, although not quite, the extremes of change that are offered in the class; but between these occur other types which show developmental phenomena more or less intermediate in their nature, being less complicated than those of the blow-fly and more complicated than those of the cockroach. An account of these various methods of development will be given under each order as it is described.

Geological Age. Like the Crustacea, Arachnida, Millipedes, and all the main divisions of the Arthropoda, with the exception of the Prototracheata (*Peripatus*), and possibly the Centipedes, Insects are an exceedingly ancient group, having left their remains in strata of Silurian age. The exact nature and affinities of these primeval remains has not, however, yet been satisfactorily determined, and some authors indeed seem to doubt whether they are rightly referred to insects. Still there is no question that species of this group flourished in abundance during the Carboniferous period; but the conclusion that all the known fossil insects from these strata form a natural order, distinct from all the existing groups of this rank can hardly be regarded as finally established, seeing that, in the opinion of some authors, they are assignable to places in our classification of existing species, and are nearly related to the orders Orthoptera (cockroaches, grasshoppers, and dragon-flies), and Hemiptera (bugs and plant-lice). In the Secondary rocks insect remains, considering the small chances of the preservation of such creatures in stratified deposits are fairly abundant; and none of the species present ordinal differences from those which now exist. So, too, the hosts of species that have been discovered in Tertiary deposits, in the amber-beds and elsewhere, are referable to existing orders.

Other Features. It has been estimated that in numbers of species insects excel all other land animals of the world taken together, and a recent computation has put the total of described forms at 250,000, and yet, according to Lord Walsingham, only about ten per cent. of existing species have hitherto been discovered. But this is not the only respect in which the animals of this class are in advance of all other groups. In brightness of colour, beauty of pattern, and gracefulness of form some of the species can hardly be equalled even by the most gorgeous birds, while in mechanical perfection of structure, as testified by activity and strength, others of the group are unsurpassed in the animal kingdom. It has been stated that if a man could leap in proportion to his stature as far as a flea can hop, he could clear at a bound a wall over one hundred feet high, and if he could sing as loudly as the cicada, his voice could be heard for a distance of many miles. Indeed, even in matters about which man is wont to especially pride himself, such as those touching social organisation, he might with advantage go to the ant

to learn wisdom, since many of the problems of modern civilisation, involved in the questions concerned in the regulation of increase of population, the proper division of labour, and the support of useless individuals, have been satisfactorily solved by many of the species of insects that live habitually in communities.

Speaking in a general way, insects may be said to be terrestrial animals, since all the species are fitted more or less completely for atmospheric respiration and for progression on the land; many of them in addition are furnished with wings, which propel them through the air with amazing velocity. In many of the orders, however, as, for instance, in the beetles and bugs, there are species that have adopted an aquatic mode of life and spend their days in fresh-water ponds and streams in various quarters of the globe. Others again, like some of the gnats and dragon-flies, live in fresh-water during the larval stages of their existence, but quit it on attaining maturity. Insects, too, are sometimes found on the coast beneath stones and seaweed at low water, but there is only one species of insect that can strictly be called marine; this is a bug (*Halobates*) sometimes met with in numbers on the surface of the ocean thousands of miles from land.

Mimicry.

The phenomena known as mimicry and protective resemblance are strikingly exemplified in insect life. The term mimicry is usually applied to cases where a species, otherwise unprotected, lives unmolested owing to its resemblance to another which is gifted with defensive weapons in the form of poison-glands, or with a nauseating flavour that renders it distasteful. Such species as these are usually rendered conspicuous by contrasting patches of bright colour. It is noticeable, for instance, that the patterns of bees and wasps are strikingly diversified, in order that the insects may be readily recognised and not slain by mistake for other species. Bees and wasps, then, being species that enjoy immunity from attack, are often imitated or mimicked by perfectly harmless flies and moths, and some beetles and animals allied to crickets similarly mimic ants. But the phenomenon of protective resemblance — or the mimicry of inanimate objects—by which a species is rendered practically invisible amongst its surroundings on account of its resemblance to a leaf, stone, twig, or bird-dropping, is of far commoner occurrence. On the accompanying Plate a few instances of this kind of adaptation to surroundings are portrayed. Figs. 12, 13, and 18 are the larvæ or caterpillars of different species of Lepidoptera, the first two in colour and shape simulating branches, and the last a snail-shell; Figs. 1, 2, 9 and 14 are leaf-like pupæ or chrysalids of other kinds of Lepidoptera; while Figs. 3, 5, 7, 11, 15, 23, and 24 are the adult stages of members of the same order under different disguises. The most noticeable of these is Fig. 11, representing a large and handsome butterfly, which, when at rest with its wings folded back, exactly resembles a dead leaf, even to the midrib and stem; while Figs. 23 and 24, exhibit two small moths, which might be readily mistaken for bird-dung. In the Orthoptera, as the insects allied to the cockroaches and grasshoppers are called, the phenomenon is carried to an extent elsewhere unsurpassed in the animal kingdom. This is well shown in the case of the leaf-insect (Fig. 4), the stick-insect (Fig. 8), and the leaf-like locust (Fig. 10). Most of the other figures on the Plate are of less importance. Attention, however, may be drawn to the water-bug (Fig. 16), the young dragon-fly (Fig. 6), the beetle (Fig. 19), the curious bugs

(Fig. 20) which in attitude and colour closely approximate to the stems or bark to which they cling. Figs. 25 and 26 show two beetles resembling sheep's droppings. Fig. 17 exhibits one of the May-flies like a dead leaf, and Fig. 21 two plant-bugs which secrete threads of white wax and appear as tufts of woollen matter.

Characteristics of the Hymenoptera. The general characters of the Hymenoptera will be more or less familiar to most readers from their acquaintance with the well-known members of the wasp, bee, and ant tribes. The scientific name by which the order is known is derived from the fact that the upper and under wings on either side are linked to each other by a series of minute hooks on the one which cling to a fold in the membrane of the adjacent margin of the other. The group includes the saw-flies, wood-borers, gall and parasitic wasps, ichneumons, ants, spider-killing wasps, solitary and social wasps, and solitary and social bees. The number of species known is from 30,000 to 40,000, though from our knowledge of the proportion which they bear to other orders, it is computed that there may be upwards of 150,000 species yet to be discovered. In specialisation of structure they undoubtedly rank amongst the most highly developed of the Insecta. The neat, agile frame, hard shining integuments, stout mandibles, strong, light wings, and movable abdomen, bearing, in the case of the female, at its apex an ovipositor of great power and precision of application, or modified into an instrument for sawing and boring in some species, and in several families becoming a sting. All these features combine with a temperament of extreme nervous energy to give them a character for general intelligence, and a power of adapting means to ends such as are manifested in no other allied order. The web-making spiders alone resemble them in this respect, and we are able to find few analogies nearer than the intelligent action, individual or concerted, of man himself. The social Hymenoptera, such as ants, bees, and wasps have solved, on their own life-plane, industrial difficulties and social problems, pressing for solution in the various societies of men. Doubtless this has been accomplished to a certain extent only at the cost of a loss of individuality such as civilised man would not tolerate for a moment. When we find that the worker-ants, bees, and wasps have, during their specialisation as workers pure and simple, lost their sexual faculties, that the members of a species of Amazon ant during their specialisation as warriors have lost the power of even feeding themselves, being entirely dependent on slaves for their food, we may well pause before concluding that such solutions of important problems are in the end for the best, at any rate so far as concerns the human race.

Without entering into the more minute details of structure, the general characters by which the order may be distinguished are as follows. The possession of four transparent wings, a head, thorax, and abdomen distinct from each other, the latter joined to the thorax by a narrow stalk, or, in the case of the *Tenthredinidæ* by a broad uniting joint. The integuments are strong, hard, shiny, and often hairy. The mandibles are well developed for biting purposes, while the subordinate mouth-parts are, in the case of the honey-bees, modified to form a long tongue-like proboscis for extracting nectar from flowers. The head is more or less globular, bearing compound eyes and several ocelli on the crown between and just behind the antennæ. The mandibles are used, besides the

mastication of food, for digging holes in the ground or for gnawing timber and various other purposes. In some ants the soldiers have the head enormously developed, as are also the mandibles; their function being to protect the society from enemies, and also to carry on war against neighbouring communities. The antennæ are in most cases long, jointed, and filiform, constituting sensitive organs of touch and recognition. The thorax is composed of the usual three pieces, prothorax, mesothorax, and metathorax. It bears the wings, four in number, above, and the legs, six in number, beneath, the latter being modified in many species for special purposes, such as, in the bees, for gathering pollen from the blossoms of the plants visited for the sake of honey. Often the legs are armed with long spines, which in the sand-wasps materially assist in the excavation of the pits in which these insects bury their victims and deposit their eggs. The wings are ample, strong, and light, formed of a transparent membrane strengthened with fine nervures or veins. The arrangement of these nervures varies much in different groups, and is of importance in the classification of members of the order. The relative importance of this character is, however, not the same in every family, being in the saw-flies, perhaps, of the greatest value. Species which are wingless in one or both sexes are found in many of the families; while in the genus *Oryura* of the family *Proctotrypidæ* the wings consist merely of a fine central stalk with a battledore-shaped plumose tip. The abdomen is united to the metathorax either throughout its whole width, as in the *Tenthredinidæ*, or, as in most of the other families, by a narrow stalk or petiole. These two characters serve for the division of the order into the groups of Sessiliventres and Petiolata. The organs of reproduction are situated at the apex of the abdomen; while in the female the instrument for depositing the eggs has become in the section Aculeata developed into a sting; in the *Ichneumonidæ* it is sometimes enormously long, and used for piercing the larvæ in which they lay their eggs. In the case of the large wood-borers (*Sirex*) it is used as a boring instrument, while in the saw-flies it is serrated on the edges and employed to wound the tender shoots on which the eggs are deposited. Amongst the *Pompilidæ* and some other families, the sting is used to paralyse the victim in which the insects lay their eggs, or leave in the cell to feed the larvæ as they hatch. Probably no pain is given to the victim, and even in the case of those grubs that feed internally upon the tissues of caterpillars in all probability less inconvenience is caused than we suppose.

In all cases the metamorphosis is complete. The egg may be laid in a cell prepared either by the female or the workers for the purpose, and the grub is fed by the attendants on a preparation of pollen or other foods specially prepared. In other cases the eggs may be laid on the foliage of trees and plants on which the larvæ feed, or they may be deposited upon or in the bodies of living or paralysed caterpillars, grubs of other species, or spiders, locusts, and the like. The *Cynipidæ* with the poison from their sting, and other causes combined, produce a large gall upon the leaves of trees, especially oaks; and on the fleshy cell-structure of these galls the grubs feed when they emerge. Larvæ of two different kinds are met with in the order. Thus, whereas those of the saw-flies have legs, sometimes even more in number than those of the Lepidoptera, the grubs of the majority lack functional legs. The former live a life of greater

liberty, feeding on the foliage of trees; the latter are free, so far as they are not confined within an egg-membrane, but being internal feeders, whether in foliage larvæ, wood, or shut up as solitary hermits, each in its several cell passes a larval period of limited freedom. It is a curious fact that the legs of some larvæ are more evident in an early than in the latter stages, thus proving that the habit of cell-life is a comparatively recent departure from a former habit, when in all probability the larval life was passed in greater freedom.

Development. The phenomenon of parthenogenesis is one which crops up in various orders of insects, being simply the production by the female of eggs or young without the fertilisation of the egg-germs within the female, by the stimulative elements necessary to the production of young in the higher animals. It is not, however, a chance phenomenon, appearing as a race-preserving expedient, on the sudden failure of male forms, but one of nature's resources for preserving the continuity of species. It is constant in many species of the Hymenoptera, in the form of what is known as the alternation of generations; in some species, however, it is supposed to be the sole form of reproduction, for the males of these species have never yet been discovered. Whether we regard the fertilisation of the female egg-germs by the male elements as dynamic or stimulative, or as merely a matter of the interchange of character determinants between the two sexes, it appears to be beyond a doubt that a continuous succession of virgin-reproductions must inevitably tend to the degeneration and ultimate extinction of the race. Parthenogenesis or virgin-reproduction may be of three kinds. First, resulting in the production of the male sex only; second, of the female alone; and thirdly, in cases when the young are produced not as eggs in the first instance, but alive, as in the case of the plant-lice or *Aphidæ*. It seems that parthenogenesis does not favour the production of one sex more than another. We should, therefore, be cautious how we accept too hastily the commonly received belief that male bees are necessarily the offspring of non-fertilised eggs. It by no means follows that because an egg was not fertilised that therefore the sex produced in it is the direct result of non-fertilisation. The question, however, is still a matter of controversy, and more evidence is needed before final conclusions can be reached.

That the members of this order are on the whole useful to man cannot be doubted,—more useful perhaps than the majority of insect forms,—whether as bees, with their honey-storing instincts, or as the ichneumon tribes dealing destruction to thousands of the larvæ—those insect pests which would otherwise work terrible havoc with our corn crops and garden produce. On the other hand, it must be confessed that the larvæ of the saw-flies often work damage to the foliage of forest-trees, while in many tropical climates ants are a devouring scourge to all that belongs to man.

Classification. We must now leave these introductory lines, but before passing on to a more or less detailed description of certain species and their peculiar characteristics of structure and of habit, the subjoined outline of classification of the various families of the order will give a general idea of the different groups, which are more obviously separated by certain broad distinguishing characters.

Order Hymenoptera.

Suborder Sessiliventres.

1. Family Tenthredinidæ—Saw-Flies.
2. „ Siricidæ—Wood-Borers.

Suborder Petiolata.

Section Parasitica.

1. Family Cynipidæ—Gall-Wasps.
2. „ Proctotrypidæ—Egg-Wasps.
3. „ Chalcididæ—Parasitic Gall-Wasps.
4. „ Ichneumonidæ—Large Larvæ-Wasps.
5. „ Braconidæ—Small Larvæ-Wasps.
6. „ Evaniidæ—Hymenoptera Parasites.
7. „ Chrysididæ—Burnished Wasps.

Section Aculeata.

1. Family Formicidæ—Social Ants.
2. „ Mutillidæ—Parasitic Ants.
3. „ Thynnidæ— „ „
4. „ Scoliidæ— „ „
5. „ Sapygidæ— „ „
6. „ Bembicidæ— „ „
7. „ Pompilidæ—Spider-Wasps.
8. „ Sphegidæ—Locust-Wasps.
9. „ Larridæ.
10. „ Nyssonidæ.
11. „ Crabronidæ—Fly and Aphid-Wasps.
12. „ Philanthidæ—Andrena Parasites.
13. „ Masaridæ—Solitary Wasps.
14. „ Eumenidæ—Mud-Wasps.
15. „ Vespidæ—Paper-Wasps.
16. „ Andrenidæ—Solitary Bees.
17. „ Apidæ—Honey and Humble-Bees.

The Saw-Fly Group,—Suborder **Sessiliventres**.

This group contains the various species of saw-flies, and may be subdivided into the saw-flies proper (*Tenthredinidæ*) and the wood-borers, or tailed-wasps (*Siricidæ*), although it also comprises the little pith-boring *Cephidæ* and the rare and little known species of *Oryssidæ*. The food of the larvæ of these insects consists entirely of vegetable matter. In the case of the first-named family, the leaves of trees and shrubs; in that of the second, the solid wood of various trees; and in the case of the third, the tender pith of the stalks of rye and also the shoots of pear and other trees. Such grubs as are internal feeders are either limbless, or have at most six more or less rudimental thoracic legs. Those, on the other hand, which live a free life and feed on foliage, are very similar in general appearance to lepidopterous larvæ, from which they may be distinguished by the

greater number of their legs; these varying from twenty to twenty-two, whereas those of the Lepidoptera have but sixteen at most. They also differ by the shining and almost naked skin, and the curious habit possessed by many of curling in the posterior segments, raising them at the same time and depressing them with a rhythmic movement. This action, which may be for the purpose of frightening away foes, coupled with the melancholy-looking eyes, gives them a grotesque appearance, not observable in the caterpillars of the Lepidoptera, save in a few instances. When full grown, the majority of the larvæ leave the food-plant and spin in or on the surface of the ground, or under dry leaves and moss, a barrel-shaped cocoon in which they pass the winter, turning to a chrysalis only a short



1, *Sirex juvencus*, female larva, pupa (all of nat. size); 2, CORN SAW-FLY and larvæ in the rye stalks; 3, *Pachymerus calcitrator*, a wasp parasitic on the above; 4, Larva and pupa of *Cephus* (enlarged).

time before the perfect insect emerges. At least a thousand species are known, though this is probably but a small moiety of those that exist.

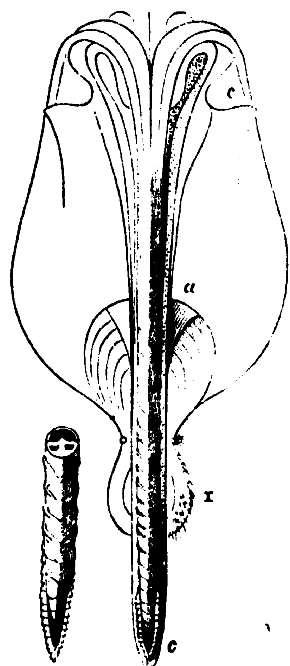
STEM SAW-FLIES,—Family *CEPHIDÆ*.

The larvæ of these slender, delicate, armoured insects pass their lives in the stems of plants or young shoots of trees; and the adults are characterised by the saw of the female being partially concealed by two integumental flaps. As an example of the typical genus, we may take the corn saw-fly (*Cephus pygmæus*), of which the perfect insect flies actively in the sunshine, flitting from blossom to blossom among buttercups in May, and thence onwards through the summer. The larvæ cause serious damage on the Continent to rye crops, and more rarely in wheat fields, where they crawl up and down within the stems, feeding on the delicate tissues. When full fed, they construct a transparent cocoon in which to pass the winter,

becoming pupæ, and a little later in May emerging as full-grown saw-flies. The parasitic insect (*Pachymerus calcitrator*) figured in the illustration on p. 15 is one of the Petiolate Hymenoptera which seems to be exclusively parasitic on the present species.

TAILED WASPS,—Family *SIRICIDÆ*.

In this family the female is furnished with a long, boring ovipositor for piercing the bark of trees; the eggs being laid in the orifice thus formed, and the larvæ feeding on the wood. In the accompanying illustration of the boring apparatus of one species *c, c, a,* shows the whole of the muscular structure with which the boring is carried out. The perfect insects are usually of large size and conspicuously coloured. Among the typical forms the common tailed-wasp (*Sirex juvencus*) is a very rare species in England, although more plentiful on the Continent. The females, which are sometimes surprised in the act of depositing their eggs on pine-trees, may be easily caught, as the ovipositor can only be withdrawn with considerable difficulty. Indeed, the abdomen breaks in half, if the insect be roughly grasped. The much larger giant tailed-wasp (*S. gigas*) is far commoner among pine-trees, and is distinguished by its bands of black and yellow. Although it does considerable damage, it does not attack a perfectly healthy tree, unless recently felled. How long the larvæ may live in the interior of the tree, and how long it is before the perfect insect appears, is not known, but cases are often quoted of this insect appearing in houses soon after their completion, having evidently emerged from the wood of the joists and beams. Another genus is well represented by the broad-bodied saw-fly (*Lyda campestris*). In this species the grubs feed on the young shoots of the Scotch fir, in which the eggs are laid. When hatched, the larvæ spin a slight web in which they remain concealed, protruding the forepart of the body when feeding on the pine needles. When all the needles in the neighbourhood have been devoured, the web is extended, so that a great number of young shoots may be embraced and destroyed. The perfect insect is shining blue-black, with some of the abdominal segments reddish yellow.

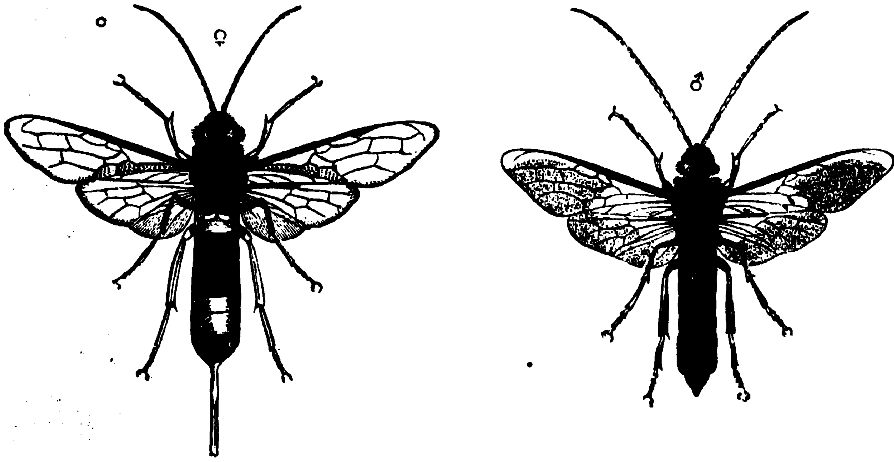


BORING APPARATUS OF GIANT-TAILED WASP (much enlarged).

TRUE SAW-FLIES,—Family *TENTHREDINIDÆ*.

In this exceedingly numerous and widely distributed group, a well known example is the pine saw-fly (*Lophyrus pini*), of which the larvæ are sometimes found in such numbers in pine-woods, where they feed upon the needles, that the trunks are often coloured yellow and the branches weighed down. Towards the end of July, the perfect insect emerges by gnawing off the cap of the barrel-shaped pupa-case. The eggs are laid in incisions made in the needles, these

wounds being subsequently closed with a viscid secretion which protects the eggs. As many as twenty eggs may thus be deposited in a single needle. When young, and also just before turning into pupæ, the grubs are very susceptible to sudden



FEMALE AND MALE OF GIANT-TAILED WASP (nat. size).

cold or heavy rain, which will kill off thousands. In addition to these destructive agencies, nearly forty different kinds of parasites infest the grubs, while mice devour numbers of the pupæ. The illustration below shows all the stages of de-



1, PINE SAW-FLY, larvæ on pine needles, and also pupæ cases shut and open; 2, BROAD-BODIED SAW-FLY, with larvæ and nest. (All nat. size.)

velopment, one of the grubs being drawn in the act of endeavouring to ward off the attacks of a parasite by the ejection from its mouth of an offensive fluid. To the same family belongs the turnip saw-fly (*Athalia spinarum*), which is one of the

most destructive species. The perfect insect appears in May from larvæ which have passed the winter in their pupæ cases, and lays its eggs upon the leaves of rape and turnips; as many as two hundred or three hundred eggs being often deposited by a single female; and in September and October the ravages of the green and black larvæ become only too evident. The grub is full grown in October, when it descends to the surface of the earth, and forms a cell of earth grains, in which it passes the winter. The majority of the members of the family belong to the typical genus *Tenthredo*, and are elegant, active insects, which alone of all the saw-flies exhibit a carnivorous habit. It is not easy to distinguish the males from the females, though the difference in the colour is of some assistance. It has been noticed, for instance, that in cases where the abdomen of the female is entirely black, that of the male is black and red. Of the green saw-fly (*T. scalaris*), the larva is common on the willow, and is pale green with black spots on the back, sometimes blending to form a central band. The pretty brush-horned rose saw-



1, TURNIP SAW-FLY AND LARVÆ; 2, ROSE SAW-FLY, male; 3, SAW-FLY, female, and with larvæ. (Nat. size.)

fly (*Hylotoma rosæ*), which in size and colour closely resembles the turnip saw-fly, extends throughout Europe, where it is common wherever rose-trees occur; the larva being found from July to October on both the wild and cultivated roses. When turning to a pupa, it spins an outer meshed envelope, and a more densely woven inner one; early larvæ pupating at once, and emerging as perfect insects early in August. The later broods, however, pass the winter in the pupa case, and appear in the following spring. The female makes an incision on the twigs of rose bushes, in which she lays her eggs, after which the twig withers away.

Typical Group—Suborder **Petiolata.**

The insects belonging to this second subdivision of the order are distinguishable from the last by the petiole, or short stalk joining the abdomen to the thorax. Sometimes this stalk is so short that the abdomen and thorax are closely united, while in others it is longer, and thus these characters form a fairly natural subdivision of the Petiolata into the pseudosessile and pedicellate forms. For general

purposes they may, however, be divided into Parasitica, or those in which the females are furnished with an ovipositor, and Aculeata, or those in which the ovipositor has become modified into a retractile sting.

GALL-WASPS,—Family *CYNIPIDÆ.*

Of the former, or parasitic section of the suborder, our first representatives are the gall-wasps (*Cynipidæ*), all of which are small and inconspicuous insects, varying in colour from black to brown and brownish red. The wings are furnished with few nervures, and the dark stigma on the anterior margin is absent; while in some species the females have the wings either rudimentary or altogether wanting. Of the galls so common on the foliage of trees and other plants, some are produced by beetles, aphides, flies (gall-midges), and others by the members of the present family and some of the *Tenthredinidæ*. In the gall-wasps each species selects some special portion of the plant for its attack, which it pierces with



GREEN SAW-FLY, *Tenthredo scalaris* (nat. size).

its ovipositor, and lays an egg in the wound. As to what exactly gives rise to the resultant gall, which follows sooner or later upon the wounded plant, is not known with any certainty. It has hitherto been supposed that the fly injects an irritating fluid into the wound, but recent researches tend to show that this serves rather as an adhesive security to retain the egg on the selected spot. It is probable that the different stimulative irritants offered, first by the inflicted wound, next by the presence of the eggs, and thirdly by the movements of the larva after it is hatched, together with the action of a fluid exuded by the grub itself, all tend to produce the strange modifications of cell structure which manifest themselves in the forms of the various kinds of galls. The larvæ of the *Cynipidæ* almost entirely feed internally upon galls produced on oak-leaves and the oak-blossoms. These galls are entirely closed, and the grub dwells within a hard cell, called the larval chamber. In some cases there may be several such chambers, as, for instance, in the Bedeguar-gall on the wild rose-tree formed by *Rhodites rosæ*. We have said that each species confines itself to one portion of the plant, and the form of the gall is the same; but an exception is furnished by the galls of *Spathegaster baccarum*, which occur upon the leaves as well as on the flower-tassels of the oak.

The phenomenon known as the alternation of generations,—that is to say, where produced generations alternate with each other in consecutive succession,—



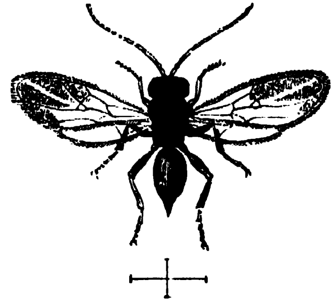
1, COMMON OAK-GALL WASP; 2, *Torymus regius*, a parasite on the same; 3, Gall of *Cynips gemmæ*; 4, Larval chamber, shut and open; 5, The same enlarged, above on the left is figured the purple hairstreak and its larva; 6, The same enlarged; 7, A gall cut through, showing the grub.



1, THE SPONGE GALL-WASP, with an old sponge-gall; beneath is a new gall, whence the wasps have not yet made their exit; 2, OAK-ROOT GALL-WASP, with its gall; 3, BRAMBLE GALL-WASP (*Diastrophus rubi*), with its gall; 4, A gall of the same slit in half; 5, *Synergus facialis*; 6, *Figites scutellaris*, parasites; 7, *Ibalia cultellator*, parasitic on *Sirex juvencus*. (All the galls and Fig. 7 nat. size; Fig. 6 enlarged.)

has been clearly shown to exist amongst the *Cynipidæ.* It is a remarkable fact, too, that the galls produced by a parthenogenetic female are different in form from those produced by a female originating from the normal sexual process. The insects produced by these different galls were for many years looked upon as distinct species. It is, of course, on the cell-tissues of the gall that the larvæ of the *Cynipidæ* feed and thrive; they themselves, however, in their turn being subject to the attacks of numerous hymenopterous parasites of various kinds.

Of the typical genus, we may take the common oak-gall wasp (*Cynips folii*) as a familiar example. It is a glistening black insect, which forms an oak-gall on the under side of oak-leaves. A parasite (*Torymus regius*) lays its own egg upon the larva of the *Cynips* lying within the gall, when the latter is about half grown. Another species (*Cynips gemmæ*) is produced from conical scale-covered galls, sprouting from the young shoots of the oak, in the interior of which the grubs feed. The illustration on p. 20 shows the gall produced by insects of this species. To the same family belongs the sponge gall-wasp (*Teras terminalis*), which emerges from many-chambered spongy galls. In spring these galls are light coloured; but later on, when the insect has made its escape, become brown. The female insects may be either winged or wingless, whereas the males are always provided with these appendages. Upwards of forty parasites have been reared from the galls of this species. Yet another familiar type is the bramble gall-wasp (*Diastrophus rubi*), which in spring produces hard and often twisted swellings on bramble-stems, from which in due course emerge the perfect insects. In the same illustration is shown the oak-root gall-wasp (*Bioriza aptera*). In this form the female is wingless, but the male is unknown. The galls are formed on the rootlets of the oak-trees beneath the surface of the ground.





ROSE GALL-WASP AND ITS GALL.

In the common rose-gall wasp (*Rhodites rosæ*), which produces the so-called bedeguan gall on roses, the larvæ are full-fed in autumn, although the perfect insect does not appear till the following spring. Their beautiful, mossy, pink-tinted galls furnish a home for many other insects, such as various species of *Synergus*, but especially parasites belonging to the families *Pteromalidæ* and *Braconidæ*. *Synergus facialis*, of which a figure is given in the lower illustration on p. 20, is parasitic on the gall-wasps. So too is *Figites scutellaris*, shown in Fig. 6 of the same illustration. These are gall-wasps, so far as structure is concerned; but as regards their habits they are in no way different from ichneumons, living in the larval state in the bodies of various insects. *Figites scutellaris*, as well as most other members of the group, are parasitic on the larvæ of the flies; while *Ibalia cultellator* is parasitic in the larvæ of the giant saw-flies.

Family *PROCTOTRYPIDÆ.*

The members of this obscure family are minute insects, with scarcely a trace of nervures in the wings in some species; and the ovipositor can be protruded and withdrawn at pleasure. Though some of the species are wholly unlike the Aculeata, yet others approach them so nearly in general characters that the present classification must be regarded as tentative. The habits of these minute insects are imperfectly known, though some are parasitic in the eggs of insects and spiders. The perfect insects, small and black, with variously-shaped plumose wings, seem to prefer damp, dark localities, such as furnished beneath fallen leaves and débris of hedges. Here also may be placed the two species of egg-wasps (*Teleas læviusculus* and *T. terebrans*), which are both shining black and very minute insects, shown in the accompanying illustration, where they are buzzing round the eggs of a moth, ready to insert their own. The females usually deposit their eggs in those of the family *Bombycidæ*, as, for instance, those of the common lackey.

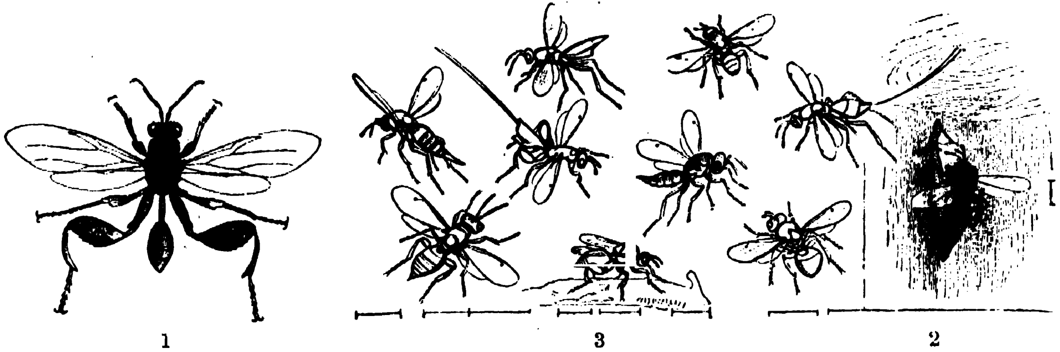


EGG-WASPS.
Teleas læviusculus; 2, *Teleas terebrans*; 3, Eggs of a moth with a *Teleas* upon them about to pierce and lay its eggs within; 4, Eggs. (All but No. 4 much enlarged.)

Family *CHALCIDIDÆ.*

This group includes a large number of small brightly-coloured insects with metallic lustre; nearly three thousand European species being known, while the tropics have not yet furnished their contingent of species. The antennæ are always elbowed, and the wings broad with few nervures. Some of the larvæ live in galls, devouring the grub of the gall-wasp or those of the other inhabitants of the galls. The members of the present order, scale-insects and plant-lice, are alike subject to the attacks of the species of this family. One species (*Leucopsis gigas*) found in Southern Europe lays its eggs in the larvæ of a mason-bee, which makes a cell of hard cement to protect its grub. Now the attacker has a boring apparatus, and the problem is how to ascertain the whereabouts of a grub, bore through the hard masonry, and lay eggs in the inmate. The cells are not distinct; but the whole number, which are made in a sort of colony, are covered with cement, so that the task is doubly difficult. With the divining powers apparently situate in the antennæ, a suitable spot is chosen, and after, it may be, an hour or so of continuous boring, the succulent morsel is reached and the egg laid. How the wasp knows where the grub lies is not known. It seems to have the power—if not of seeing—at any rate of feeling literally through a brick wall. One of the largest members of the family is the gouty-legged wasp (*Smicra clavipes*), the egg of which is laid in the larvæ of certain water-insects. The wasp is glistening

black, with reddish legs, the wings being better furnished with nervures than in other members of the family. In the chrysalis-stinger (*Pteromalus puparum*) the egg is laid in the chrysalis of several common butterflies during summer, while the larvæ remain in their host all through the winter, sometimes to the number of fifty.



1, GOUTY-LEGGED WASP; 2, CHRYSALIS-STINGER; 3, Sketches of various *Chalcididæ* (enlarged).

THE ICHNEUMON-WASPS,—Family *ICHNEUMONIDÆ.*

The species included in this vast family number upwards of six thousand, and doubtless more remain to be discovered. The majority are parasitic on the larvæ of Lepidoptera, rendering good service to the agriculturist and gardener by holding in check the enormous quantities of larvæ hatched every year. Some, however, attack other insects as well as spiders. The family is distinguished by the variation of the wings, though these characters vary too slightly to be of much value for generic or specific purposes. The antennæ are of uniform thickness, many-jointed, and, as a rule, filiform, though in some exceptional cases club-shaped. The ichneumon-wasps do not hum, either when quiescent or on the wing, and are thus enabled to approach the victim within whose body they wish to lay their eggs with a greater chance of success. Having selected a suitable caterpillar, the female deposits an egg with her ovipositor either on or beneath its skin. The egg soon hatches, and the grubs feed upon the tissues of the larvæ until full fed, when they pupate in or around the now almost empty skin of the caterpillar. The family has been divided into five groups, sufficiently distinguished from each other in their typical forms, but merging into one another through transitional species. Our first example is the ichneumon (*Exenterus marginatorius*) figured in the illustration on p. 24, which belongs to the subfamily *Tryphoninæ*, and is found chiefly in pine-woods, where it is parasitic on *Lophyrus pini*, described on p. 16. The female attaches an egg by means of a hooklet to the skin of the green larvæ, when nearly full grown. When the insect forms its barrel-shaped pupa, in which to pass the winter, the parasite remains attached to the skin of the larva, whose tissues it gradually absorbs. The perfect insect makes a small hole in the pupa-case when it emerges, and does not, as does *L. pini*, bite off a little cap at the top. Another type is *Bassus albosignatus*, which frequents the honey-dew dropped by aphid colonies. It lays its eggs on various larvæ which feed upon the

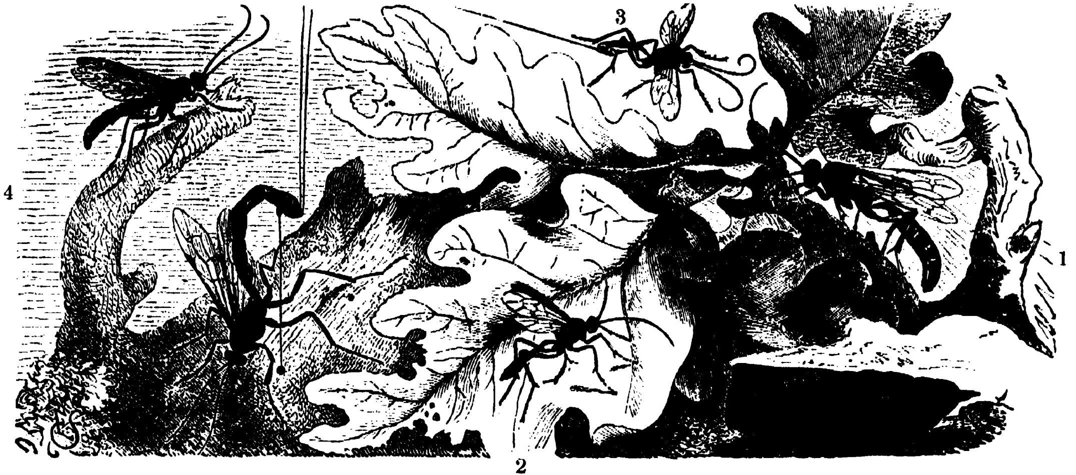
aphides. In the allied genus *Banchus*, the species are parasitic on caterpillars, especially those of the hawk-moths. The affected larvæ do not even reach the pupal state, but shrivel away, while the parasites form pupæ within the empty skin. The members of the typical genus and subfamily, such as *Ichneumon pisorius*, are among the largest and most brightly coloured of the group; their colours, which are white, black, red, and yellow, occurring in great variety of combination. The females are usually more brightly coloured than the males. The former sex is easily distinguished by the filiform antennæ, which are sometimes knotted, and may be observed to coil after the insect is dead. Many fine species may be taken from moss in the spring, where they hibernate, though the great majority appear in the summer and do not live through the winter. The European species named is one of the largest, and may be regarded as typical of the general appearance of members of the family. It is found from June onwards



1, *Exenterus marginatorius*, about to sting the larva of *Lophyrus pini*; 2, Pupa-case of the latter with the parasite emerged; 3, With the proper saw-fly emerged; 4, *Bassus albosignatus*, about to attack a Syrphus-larva; 6, *Banchus falcator*; 7, Pupa of the ichneumon. (Nat. size.)

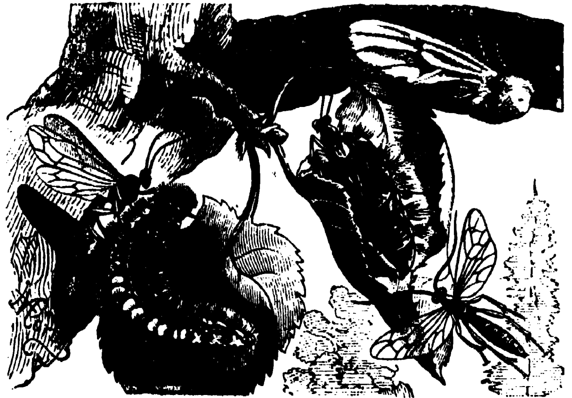
in pine-woods, where it attacks the larvæ of the pine hawk-moth, depositing a single egg in each victim. The caterpillar maintains its general health, and passes into the chrysalis state as though nothing were amiss; the only difference being that a large ichneumon-fly emerges instead of the expected moth. An illustration of the parasite is given in the illustration on p. 25, together with a pupa-case, with the cap removed, whence the fly has escaped. Of the other forms here figured, the male of *Cryptus tarsoleucus* gives a good idea of the general appearance of the males of the ichneumons, with their narrow elongate abdomen. All the species of *Cryptus* are parasitic on the larvæ of the saw-flies, and the *Bombycidæ*; the female laying several eggs in each larva. A fine handsome form is the one known as *Mesostenus gladiator*, on account of its long needle-like ovipositor. It flies in June, and may be found in the vicinity of old crumbling walls, where bees of various kinds make their nest in the holes and crevices. In the same illustration is figured *Ephialtes manifestator*, representing the subfamily *Pimplariinæ*. In some members of this group the ovipositor issues from a ventral cleft in the abdomen, and in others from

the tip itself; the instrument being sometimes three times the length of the entire body. All the species of the genus are much alike in general appearance, the smaller kinds being parasitic on small larvæ, and the larger on those of superior size. They may be seen flying about in woods in summer, in search of the wood-



1, *Ichneumon pisorius*, male, and empty pupa of pine hawk-moth, whence the parasite has emerged; 2, *Cryptus tarsoleucus*, male; 3, *Mesostenus gladiator*, female; 4, *Ephialtes manifestator*, male and female, the latter laying her eggs. (Nat. size.)

boring larvæ in whose bodies they lay their eggs. With intelligent agility the female hurries over the trunk, but by what sense she ultimately detects the presence of a larva within, and directs the ovipositor straight down to the spot, it is impossible to say; sight can be of no assistance, nor, one would judge, can touch. Can the antennæ be used, as the divining rod is supposed to be used in the search for water, when commonsense methods have failed? Possibly, however, the sense of smell assists, and thus the seemingly miraculous becomes once more a common-place. The females apparently follow the borings of the larvæ, for it would be next to impossible for them to penetrate the hard fibres of the timber in which their victims burrow. One of the commonest members of the family, and one of the largest English forms, is *Pimpla instigator*, which preys upon many species of larvæ, especially those so destructive both in gardens and the forests. The perfect insect may be seen on tree-trunks, in woods and hedgerows, searching for larvæ, with its wings raised, ready for instant action. The illustration represents this species attacking the larvæ of the satin moth.



Pimpla instigator, female to the left, stinging the larva of the satin-moth. To the right is the moth, beneath it the pupa, from which emerges the adult, while the male of the parasite is seen below.

Family *BRACONIDÆ.*

The members of this family are very similar in general appearance to those of the last, though the differences in the number and form of the cells enclosed by the wing-nervures forms an easy distinction. In habits the *Braconidæ* are similar to the *Ichneumonidæ*, attacking as a rule the larvæ of Lepidoptera, although they are found as well in those of other insects. Upwards of a thousand parasitic grubs of the genus *Microgaster* have been taken from a single caterpillar. It must be remembered that the grubs are not in reality gnawing at the vitals, but are nourished by the fluids circulating through the system. As an example of the family, we may take the genus *Microgaster*, which comprises many of the commonest species. The females of all, except two which are parasitic on *Aphides* and the eggs of spiders, attack the larvæ of Lepidoptera, especially those clothed with hair. They are themselves the victims of the attacks of a species of *Pteromalus*—a genus of Hymenoptera briefly noted above.



Microgaster nemorum, female (enlarged); its larvæ are feeding upon a large caterpillar (these of the nat. size).

OTHER FAMILIES.

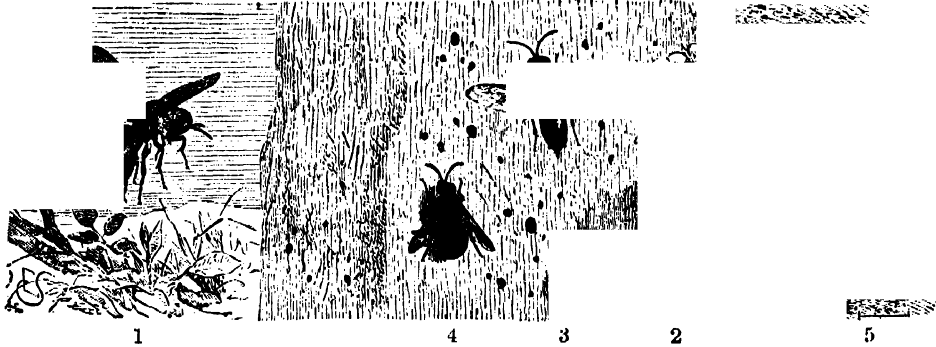
In the family *Evaniidæ* the abdomen is attached above the middle of the metanotum, not to its lower margin. Among these is the javelin-wasp (*Fænus jaculator*), a species parasitical on Hymenoptera which breed in old walls. In the typical genus *Evania* the species are believed to be parasitic on the cockroach, depositing their eggs in the egg-capsules, and this habit will account for the presence of a certain species on board ships, where cockroaches abound. The members of the family *Chrysididæ* are not easily mistaken for those of any other, being of moderate size, and distinguished by the brilliancy of their colour, not only in the tropics but even in temperate climates. The integuments are more or less coarsely punctured, and the whole body glistens with metallic lustre, golden-yellow, fiery-red, blue, and green, all these being as a rule in combination. The perfect insects are most numerous in the summer months, and may be observed amongst flowers, on decaying timber, old walls, and other suitable hunting-grounds. The females lay their eggs in the nest of the various burrowing Hymenoptera. It is probable that the grub devours the store of food garnered for its own progeny by the careful mother. Possibly it makes little distinction between the food supply and the tissues of the organism nourished by them. The common ruby-tailed wasps belong to this family.



JAVELIN-WASP, *Fænus jaculator* (nat. size).

The golden burnished wasp (*Stillbum splendidum*) is entirely steel-blue or

golden-green. It occurs on the shores of the Mediterranean, and is also found in Asia. It is one of the largest of the European forms. Among these, the burnished blue wasp (*Chrysis cyanea*) is universally distributed throughout the whole of Europe. The females lay their eggs in the larvæ of those species of Hymenoptera which make their nests in bramble-stems. The common golden wasp (*C. ignita*) may be seen flying in search for the larvæ of Hymenoptera, whose burrows are made in old posts, walls, sand-pits, and other such places. Of the royal gold-wasp (*Hedychrum lucidulum*), another of the commoner and more beautiful species, a figure appears in the accompanying illustration. In the same



BURNISHED AND GOLD WASPS.

1, Golden burnished wasp; 2, Burnished blue wasp; 3, Common gold wasp; 4, Royal gold wasp, female; 5, Brazen-tailed wasp.

illustration is also shown the brazen-tailed wasp (*Elampus æneus*), of which the female deposits her eggs in the grub of a small species of the *Sphegidæ*.

THE ANTS,—Family *FORMICIDÆ*.

The ants bring us to the section Aculeata, the members of which differ from the preceding section in that the females are furnished with a retractile sting in place of an ovipositor. As a family, ants are characterised by having the first segment of the abdomen and sometimes also the second reduced in size to form a stalk for the rest of the abdomen. The workers, moreover, are without wings. On account of their remarkable habits and intelligence, these insects demand a fuller notice than is accorded to other groups. As regards their visual powers, ants are very sensitive. While disliking any strong light suddenly thrown into their nests, they prefer rays transmitted through a red medium, but object more to those coming through green and yellow, while those through a violet medium they abhor. Though sight is well developed, hearing seems much less so; vibrations of the air produced by tuning-forks, violin strings, or whistling, being little heeded. Neither has any sound emitted by the ants themselves been detected, even with the most sensitive instruments. The sense of smell is evidently keen, for brushes dipped in scent arouse distinct curiosity. When the scent left in its tract by an ant is obliterated, the ants next following are baffled, like hounds at fault, until, after a little casting about, they pick it up on the other side. In seeking for an object of whose existence and position they are aware, ants make

use of both sight and smell; but it is in the latter that they place most confidence, for if the object be removed only the space of an inch from its position, the ant in search of it will make a number of cross journeys over the old resting-place before it is successful. The scent, too, seems to be rather that left by former footsteps than proceeding from the object itself. This sense of smell, and perhaps touch combined, is obviously manifested in the caressing or recognition of friends with the delicate antennæ. The mysterious sense of direction is, after all, but sensitiveness to the direction in which the rays of light fall from a luminous object, and, as such, is but a form of sight. This is proved as follows:—Ants made to cross a wooden bridge would, in most cases, instantly turn round, if their heads were turned in an opposite direction, by the bridge being made to rotate on a point. And they would at once lose the sense of direction if light was shut out from the artificial tract prepared for them, while if the candle were moved round in the same direction as the bridge over which they travelled, though the direction be changed, the ant does not become aware of it, because the rays of light fall from the same point. Nevertheless, the sense of smell is evidently the stronger, for ants carrying larvæ from a cup to the nest still continue their course, although the board on which they are travelling be turned right round. They follow the scent of former tracks rather than take notice of the direction in which the light falls.

It is obvious that without some faculty representing, at anyrate, the rudiments of memory, ants would not be able to recognise even the scent left by comrades on the ground, nor would they persistently seek for an object which had been removed. They exhibit, however, all the phenomena of true memory. A fact, by repetition, becomes more firmly fixed as a sense-impression on their brains. It fades away if not refreshed. Evidence in favour of a highly-developed sense of memory is furnished by the fact that ants from a certain nest were in the habit of journeying year by year, during the season of activity, to a chemist's shop, six hundred yards distant, to a syrup-jar. It is scarcely likely that the jar was found every year by fresh ants, so that memory alone will account for the circumstance. It is perhaps in the recognition of friends, however, that ants manifest the most extraordinary powers of memory. They invariably recognise a friend, while a stranger is almost instantly slain. Ants held captive for months, and returned to the nest, are recognised as lost friends, and caressed with the antennæ. This recognition might be merely a matter of the well-known odour of a friend; but even then it must be a national smell, for it is scarcely possible that each can recognise the personal scent of every individual. Not only do they recognise the perfect ants, but even the offspring, or eggs, removed and hatched in other nests, and returned home full grown, are recognised as kith and kin, while their foster-mothers are slain. One can hardly suppose that the scent, unless such be inherited, would account for such recognition.

Whereas ants show evidence of such feelings as rage and combativeness, the emotion of sympathy is by no means as constant or intense as might be supposed from their general intelligence and power of recognising friends. Mutilated ants, and those in difficulties, are passed by on the other side; but an intoxicated ant staggering in its tracks does not fail to excite astonishment, and is carried off as a sort of curiosity to the nest. Chloroformed ants, however, are dropped into the

water, where they were, of course, motionless. That ants have the power of communicating intelligence admits of no doubt. Two ants were introduced, the one to three hundred or six hundred larvæ in one glass, the other to two or three in another glass, each took a larva and returned to the nest. A larva was added to the second glass every time one was taken. In forty-seven and a half hours the ant which was introduced to the six hundred larvæ had brought two hundred and fifty-seven friends to help, while the other in fifty-three hours had brought but eighty-two.

The swarms of ants which in spring rise in clouds are males and females. This is their nuptial dance, and for hours they circle and sport in the sunshine. The males fall and die, or are destroyed by numerous foes. Nor is any assistance offered them by the workers, who well know that their vocation in life has been fulfilled, and they themselves are no longer of any use. The females having divested themselves of their wings, with claws and legs, set about founding new colonies. The eggs, however, must be nursed if they are to hatch, and are subjected to much licking by the nurses. Then the larvæ must be fed; next, they are carefully cleansed and carried for their daily walk through the lanes of the nest. Not even after the grub has become a pupa is the ant allowed to emerge without assistance. Büchner writes that "the little creature when freed from its chrysalis is still covered with a thin skin, like a little shirt, which has to be pulled off. When we see how neatly and gently this is done, and how the tiny creature is then washed, brushed, and fed, we are involuntarily reminded of the nursing of human babies." Next, they are taught their domestic duties, and to distinguish between friend and foe. If the nest is attacked, the older and more experienced fight, while the younger members remove the pupæ to a place of safety.

Ants not only feed upon the honey-dew dropped by plant-lice upon leaves, but also rear aphide eggs, and feed the insects for the sake of their secretion. Tunnels, or covered ways, are made by some ants up the branches of the trees where the aphides live, so that the insects are enclosed and kept prisoners. Certain portions of the tunnels are enlarged to form stables, where the aphides are penned, the doors being large enough for the narrow ants to enter and leave, but not for the rotund plant-lice to escape. The 'cows' are induced to part with a drop of honey-dew by a gentle stroking with the antennæ, and general encouragement of other kinds. Ants are far in advance of human dairymaids in the matter of tact in dealing with their cows. Colonies of aphides have been carried by ants to fresh pastures.

It is no long step from cow-keeping to slave-making. At least three species of ants indulge in this reprehensible practice. A raid is organised against a neighbouring nest—warriors and workers are slain, and the pupæ carried off, hatched, and reared, soon to work and fight for their masters in the land of their captivity. In some cases the slaves are kept for indoor occupation, and are carried off, as part of their goods and chattels, by their masters, when they migrate into new quarters. Another species does not work at all, neither males nor females; the workers—sterile females—capture slaves, but do no more. They neither feed their young, nor make their nests,—a city-state entirely dependent on slave-labour. Not only, however, do slave-making ants engage in expeditions against

other communities for the purpose of securing servants; but even many ants, whose energies are confined to agriculture, not infrequently wage war for the sake of plunder on others whose habits of life are similar. An expedition of the former tribes usually consists of a general attack upon the nest of a species which they are in the habit of enslaving. Single scouts are sent out to reconnoitre, whose business it is to investigate the position of the nest and the whereabouts of the entrances. Having satisfied themselves of the feasibility of an attack, they return to their own nest, and summon forth the hosts of ferocious warriors. These encouraging one another with taps of the antennæ, march on the unhappy colony, whose baby inhabitants they propose to enslave. Of all the warriors the most warlike are the amazons (*Formica rufescens*), robber-ants of great size, strength, and courage. A column is formed, and, guided by the scent of their prey, as they come within the radius of their victims' pathways to and from their city, in hundreds they rush onwards. An hour, it may be, after the start, the nest is reached and entered, and soon the struggle becomes a furious battle, on the one hand to save, on the other to carry off the larvæ. Up the neighbouring trees the owners fly with their precious burdens, a harbour of refuge, secure from danger, for here the Amazons cannot follow—specialised to kill but not to climb. Others hang on the flanks of the retreating columns and harass the thieves bearing off the tender pupæ. A nurse seizes one end of her nursling, the Amazon has the other, imperceptibly the jaws of the latter steal up, still holding on, towards the far end, till the nurse's head is pierced. Sometimes the Amazon lets go, and the nurse is gone in a trice, and the pupa with her, while the warrior contents itself with a vicious grin as the embryo slave vanishes into the tree-tops. The slaves left behind in the city are ready to receive the plunder; and soon more slaves are hatched, whose prison is now their home, for they have never been conscious of another. But success does not always smile upon their expeditions; an entire army may lose the way, courage may fail the leaders, disputes may arise, and general unaccountable want of *esprit de corps* breaks their resolution, and the attack is abandoned. Many a warrior loses its way emerging from the ravaged nest by passages which open to the thicket far from those they entered by. The sense of smell is of no avail, that of direction does not rise to the occasion.

Another robber-ant (*Formica sanguinea*), not so well furnished with offensive weapons, but larger and more intelligent than the former, also sallies forth in search of slaves. Both may meet in combat on the march, and the dead and dying mangled remains, and heads and legs nipped off, bear witness to the consequences. These robber-ants do not attack a nest with a rush, as do the Amazons. They lay deliberate siege to it, surround it, securing the entrances and exits. None of the inhabitants are allowed to pass if they carry pupæ.

Of the other inmates of ants' nests such as beetles, crickets, spiders, wood-lice, and the like, want of space forbids mention, and, indeed, the reason of their presence is not obvious. The supposition that they are kept as pets possibly derives support merely from the analogy drawn from similar whims amongst human beings. That ants sleep is an undoubted fact, and so too that they bestow much care upon their toilet, assisting each other in this respect. Bates writes that "here and there an ant was seen stretching forth first one leg and then

another, to be brushed and washed by one or more of its comrades, who performed the task by passing the limb between the jaws and tongue, finishing off by giving the antennæ a friendly wipe." Recreations, too, are not unknown to them; running after each other in hide-and-seek, followed often by a rough-and-tumble game. Stranger still, they hide away the dead bodies of their friends in chinks and crevices far from the nest, and thus perform a sort of burial. That the habit is more than the desire to be rid of what is useless, or may be injurious, seems doubtful; unless, indeed, such device lies at the root of all funeral customs, as is not improbable.

Of the British species, the largest is the red wood-ant (*F. rufa*). It abounds in fir-plantations in the southern counties of England, and the huge heaps of pine-needles it gathers over its nest are familiar objects to frequenters



1, HONEY-POT ANT; 2, PARASOL-ANTS on the march; 3, Dwellings of husbandmen ants. (Nat. size.)

of the forests; while the size, ferocity, and numbers of the ants themselves become a nuisance even before their ways have ceased to be amusing. If the nest be disturbed, the fumes of formic acid burst out full in the face of the intruder, while the jaws of the enraged inhabitants render further operations impossible. Numbers of nests, however, are annually ransacked of their pupæ for young pheasants, which often seem surprised by the flavour of the ants, which they pick up with the pupæ. Highways cross the paths in every direction around the nest, and the ants may be seen coming and going continuously throughout the day, bringing in twigs, caterpillars, and fragments of all kinds of insects, to be safely stored away in the nest. Still larger is the Hercules ant (*Camponotus herculeanus*), which inhabits wooded highlands in continental Europe, and constructs its nest in decayed tree-trunks. The female measures more than half an inch in length; and the insects, when swarming, gather in a cloud around the base of some tree. In colour the body is glistening grey, while the tips of the wings are yellow. The honey-pot ant (*Myrmecocystus mexicanus*), of which the

habits are alluded to above, inhabits the highlands of Mexico and South Colorado. The nest is constructed in the ground, usually beneath hillocks, in a gravelly soil, and contains passages and chambers arranged in different storeys, some for food, others for the larvæ, and the third for the honey-pots. The inhabitants condemned to servitude in the honey-secreting department of this community are never allowed out. An allied species is found in Australia. Still more curious is the South American saüba, or parasol-ant (*Œcodoma cephalotes*), dreaded on account of the havoc it works amongst the foliage of plantations. Agriculture, too, becomes next to impossible where these destructive insects abound. They are not without their uses, however, for the Indians regard the females when full of eggs as a delicacy. Seizing the insects by the thorax, they nip off the luscious morsel with their teeth, much as we may see monkeys behave towards a fly. The nests of this species are prodigious. Bates speaks of hills forty yards in circumference, or about twelve yards across, while others are of even larger size. This hill, huge as it is, is merely the outer covering of a network of galleries extending deep and far into the ground, with many outlets into the surrounding country, usually carefully secured. The workers, of which there are two forms, look after the progeny and gather food; while the soldiers, with broad heads and terrible jaws, sally forth if danger threatens their citadel. The stronger workers march in daily procession to the plantations in search of leaves, and return, each with a piece securely held in its jaws. The more slightly built remain at home, engaged in the less arduous operations of domestic economy, and rarely venture far from their nest. These leaf-cutting expeditions are directed chiefly against coffee- and orange-plantations, and the ants, accompanied by a detachment of soldiers, partly no doubt to keep order, and more especially to guard the caravan against freebooters, march in large columns to the groves, climb the trees, and begin to reap their daily harvest. Each ant having cut with its toothed mandibles a piece of leaf half an inch in diameter, descends the tree, holds its booty high in the air, edge upwards, and so homewards. The leaf-discs thus held above their heads have earned for these insects the name of "parasol-ants." The path they travel on is soon beaten down with footsteps, and worn till it becomes a deep groove; but even height does not end their activity and mischief, for they make raids on the houses of the planters in search of groceries and sweetstuffs, appearing often in swarms. There are several species of this genus with similar habits, and all are known by the natives of Brazil under the single name saüba. An illustration of one of the leaf-cutting expeditions returning homewards is given in the illustration on p. 31.

Family *MUTILLIDÆ*, etc.

The species included in the families *Mutillidæ*, *Thynnidæ*, and *Scoliidæ*, number from twelve hundred to fifteen hundred. The females of members of the first two are wingless, while those of all three families possess a formidable poison-sting. Of the European *Mutilla europæa*, the males may be seen, though not commonly, amongst flowers, and frequenting foliage infested with aphides. The wingless female may, however, often be met with on sandy commons in summer. The larvæ are found in the nests of humble-bees, where they feed upon the grubs.

All species of the family, however, are not parasitic on humble-bees, for in South America, where the tribes of the former are scantily represented, those of the latter are numerous. Of the third family, we take as example the formidable *Scolia nemorrhoidalis*, which is found in Turkey, Hungary, Greece, and Southern Russia. Not very much is known of its habits and life-history, but such as is points to a larval life parasitic on various beetles; while other members of the



Mutilla europæa—1, Female; 2, Male; and *Scolia nemorrhoidalis*—3, Male; 4, Female.

family have been taken from nests of the parasol-ant. In the *Scolidæ* the wings are present in both sexes. Figures of the male and female are given in the illustration above.

Family *BEMBICIDÆ.*

The members of this family are distinguished from the under-mentioned *Sphegidæ* by the formation of the labrum, which is much produced. In general appearance they resemble the hornets and larger wasps. *Bembex rostrata*, figured on p. 35, is found not uncommonly throughout Europe, but becomes more local in the northern countries. The insects fly in circles, with a loud hum of their powerful wings round and round the burrows which the female makes in the loose sand or earth. Here are stowed away the bodies of large flies, reduced by an application of the sting to a state of unconsciousness; and in each nest a single egg is laid, the grub when hatched feeding upon the food which it finds placed within its reach.

Family *POMPILIDÆ.*

In this group the males are characterised by their slender form and small size; and both sexes may be recognised by their energetic hurrying to and fro with quivering wings and antennæ, moving rapidly on all sides, as they search sandy commons for a suitable spot to burrow in, as well as for the spiders which they numb with a sting and store up for the larvæ. The members of the family are universally distributed, being larger and more brilliant in tropical countries.

Some make their nests in the beetle-borings of old trees and posts, and prey upon all kinds of insects and their larvæ; others prey exclusively on spiders, and confine their burrowing operations to sandy soils. Not only do spiders of the family *Lycosidæ*, which run freely on the surface of the ground but make no nest, fall victims to the *Pompilus*, but the *Epeiridæ* are snatched from the very centre of their maze and carried off, their powers of resistance rendered futile by one paralysing stroke of the poisonous sting. Well are these spiders aware of the danger, for they drop instantly from their webs into the herbage when the hum of wings warns them of the near presence of a wasp. Others, however, whose staple food consists of bees and wasps, are not so easily alarmed, and learn to distinguish between friends and foes. The figured *Pompilus natalensis* is of considerable service in Natal, since its habit is to search every nook and cranny for house-frequenting spiders. Up and down the windows, in and out amongst the rafters,



1, *Pompilus natalensis*; 2, *Pompilus trivialis*; 3, Larva of latter on garden spider; 4, *Priocnemis variegatus*; 5, *Agenia punctum*, with its two cells.

the female passes to and fro in search of the large spiders which lodge in their webs hung up amongst the woodwork. The victims when captured are buried with the egg in a hole in some suitable corner within or without the house. A large species of this genus attacks spiders of the genus *Lycosa* on English commons, and buries them in a somewhat similar fashion. The second species figured in the illustration (*P. trivialis*) also attacks spiders, especially *Lycosa inquilina*.

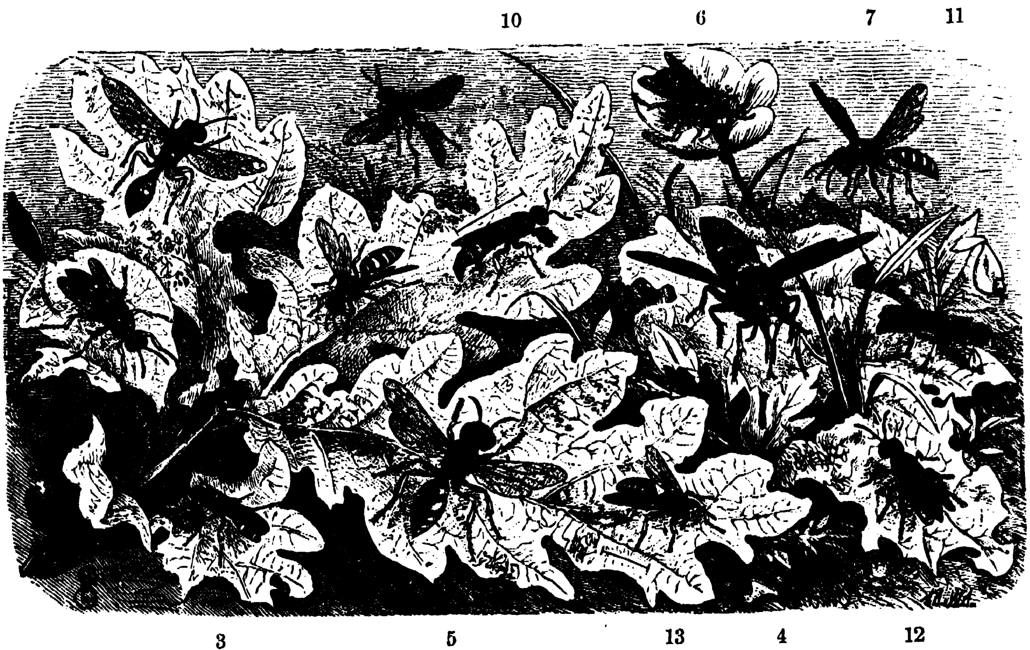
Family *SPHEGIDÆ*.

Many of the handsome insects belonging to this family are uniformly black, black and red, or yellow and black. The majority, however, are black with brilliant yellow or white markings, and shine with the lustre of burnished metal. These markings are very variable even in the same species, rendering their identification difficult for the student, though on account of that contrast of colour, and the

activity of their movements, the members of this family are amongst the most attractive of all hymenopterous insects. Some species prey upon lepidopterous larvæ, others on grasshoppers, while another provisions its nest with three or four crickets. These latter, however, are not captured without a severe tussle. The *Sphex* leaps upon the cricket's back, delivers a couple of stings, and all is over.

Family *CRABRONIDÆ.*

The numerous members of this family are usually black with yellow markings. Their nests are formed either in the ground or in decaying timber; the tunnels of wood-boring beetles being utilised in the latter case. While the smaller species feed chiefly on aphides, the larger kinds are more partial to flies. Figures of three species, viz., *Crossocerus scutatus*, *C. elongatulus*, and *Crabro patellatus*, are given

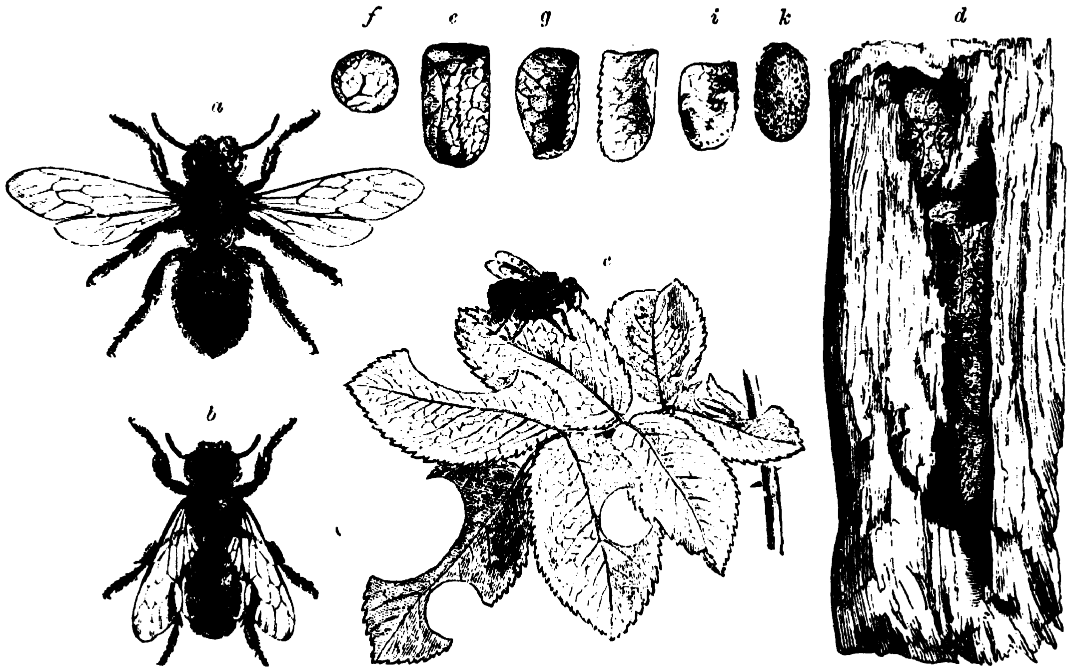


Mellinus arvensis—1, Male; 2, Female; 3, *M. sabulosus*; 4, *Bembex rostrata*; 5, *Philanthus triangulum*, *Cerceris arcuaria*; 6, Male; 7, Female; 8, *Trypoxylon figulus*; 9, *Crabro patellatus*—Female; 10, Male; 11, *Crossocerus scutatus*—Male; 12, *C. elongatulus*; 13, *Oxybelus uniglumis*. (1, 10–13 enlarged, the rest nat. size.)

in the annexed illustration. Another form is *Mellinus arvensis*, usually met with in pine-woods, where it may be seen searching about on the sandy soil, and is particularly fond of the honey-dew deposited by aphides. A smaller form (*M. sabulosus*) is likewise shown in the illustration. The same illustration also shows *Trypoxylon figulus*, a black insect, which may be observed throughout the summer flying busily to and fro among posts and decaying trees. A variation in the mode of making its cell will be noticeable. Selecting a long tunnel, the female brings in aphides or small spiders, lays an egg, deposits a suitable supply of food, and fits on the top a wad of mud, above this again another cell is constructed, similarly capped with mud, and so on till the tunnel is full.

Family *PHILANTHIDÆ*.

As an example of this family may be taken *Philanthus triangulum*, the larva of which feeds upon the honey-bee, and other members of the same group. In the illustration on p. 35 a figure of this species is given. Since, at least, five bees are provided for each larva, the havoc caused in hives where these insects abound must be considerable. A separated nest, in some warm sunny slope, is made for each egg. Another form is *Oxybelus uniglumis*, figured in the illustration on p. 35. In this species the female excavates tunnels in sandy ground, to which the sunshine has free access, and flies are mainly used to provision the nest, as a rule one only to each cell. The fly is attacked from above, knocked down, stung in the neck, and carried off to the nest. A third form (*Cerceris*



COMMON LEAF-CUTTER BEE. *a*, *b*, Female and male (enlarged). *c*, Rose-leaves with several pieces clipped out and a bee at work; *d*, Nest in a willow stem; *e*, A single cell; *f*, The lid of same; *g*-*h*, Pieces of leaf; *i*-*k*, Side pieces.

arenaria), shown in the same illustration, is a black insect with yellow bands on the abdomen, as are most of its kindred.

WASPS AND BEES.

Before taking into consideration the families into which these groups are divided, it is advisable to give an account of some points connected with their habits, as well as a notice of their special senses. As regards sight, the large size of their compound eyes, in addition to the presence of ocelli, indicates their high degree of visual power. In respect of perception of colour, experiments have shown that if honey be placed on cards of different colour, bees show a decided preference for special tints; orange and yellow being the prime favourites.

Similarly, no doubt, the colours of flowers have a greater or smaller degree of attraction for these insects. Indeed, it is beyond question that the fertilisation of flowers by the visitation of bees has tended to the development of the special colours patronised by the insects, while blossoms which were of less favourite hues have gradually disappeared. Black, white, and green flowers are not so common as yellow, orange, blue, or red; and black is less prevalent than either of the others. Although experiments to prove or disprove the sensibility of bees to sound have so far been negative, yet from the fact that they are exceedingly sensitive to a certain peculiar cry occasionally emitted by the queen, which acts like an electric shock, it would appear that hearing is likewise well developed. That bees and wasps are able to find their way, and to fly off apparently without hesitation straight for home, needs no proof. But this power does not necessarily indicate some mysterious sense of direction, enabling them to perceive their bearings by occult means. Rather may it be looked upon as due to the ordinary observance of conspicuous landmarks, such as are utilised for guidance even by man himself. Bees, for instance, have been taught the way to a store of honey by the repetition of single experiences, proving that they pass from the unaccustomed to the well-known, little by little. Naturally, the direction of a point to which whithersoever they may wander out, they must invariably return many times a day, soon passes from the sphere of calculation and enters the region of simple intuition; so rapid and unconscious are the various acts of perception involved. That these insects do thus take note of landmarks has been shown by Bates, who describes how a sand-wasp carefully marked the spot where half of a larva had been left by circling round and alighting in the vicinity. And even then, when it returned, though it flew many times straight to a certain conspicuous leaf close above the booty, doubtless a landmark yet it could not for a long while—and after repeated pounces in the wrong direction, and more it seemed by good luck at last—succeed in finding it. No one who has heard the cry of an angry wasp, and experienced the pain which has followed, will doubt that anger and malice have their places in the wasp's nature. Often do these insects seem to make straight for an innocent bystander, and sting from pure spitefulness. Sympathy for the ailing and wounded, as amongst the ants, so amongst the bees, seems to be more noticeable than it is towards those actually in distress,—though uninjured. It has been doubted, indeed, whether bees show any affection for one another; the caressing antennæ, as well as the personal attentions to each other so noticeable in the case of ants, are certainly lacking. As in ants, however, the antennæ seem to be the chief organs of communication.

As regards habits, there are two chief operations in which bees and wasps engage, namely, the procuring of food and the rearing of a progeny. This food is of two kinds,—honey gathered from the nectaries of flowers, and bee-bread, or flower-pollen moistened with honey, kneaded by the workers, and stored away, for feeding the larvæ. The workers, or honey-gatherers, do not bring in more than one sort of pollen at the same time; and when the nurses, or domestic bees, receive the pollen from the honey-gatherers they keep it carefully separate. The sort of pollen is more nutritious than another, and a female larva fed on the more nutritious bee-bread will become a queen or fertile female, and one hive cannot afford

more than a few of such luxuries. Those fed on the less nutritious bread turn out workers, or non-fertile females. For the males special conditions are arranged by the queen when laying the eggs. Royal cells, framed for the feeding of queens, are much larger than those for workers. In secreting wax for the cells, bees having eaten as much honey as they can conveniently carry, hang in a cluster from the top of the hive. Soon the wax begins to burst from glands beneath the edges of the segments of the body, and is rubbed off with the legs. Cell-construction now begins, and in addition to the wax, a sort of resinous cement, drawn from the sap of conifers, is used to strengthen the walls at their angles, and also to cover the inside of the hive. The six-sided form of the cells of the honey-bee appears to have been evolved after ages of gradual modification from the simple cylinder which would be formed by a cylindrical body—as that of a bee—moulding wax around itself; this form alone admitting of the greatest number of cells being placed side by side, and tier by tier, without leaving waste

Honey-Bee.

INMATES OF A HIVE.

-1, Queen; 2, Worker (non-fertile female); 3, Drone or male; 4, Mandible from outside. (All slightly enlarged.) B, Hind-leg of worker; *c*, Thigh (*femur*); *b*, Shank (*tibia*); *a*, First tarsal joint. C, Egg (much enlarged). D, Larva and pupa (nat. size). E, Longitudinal section of the abdomen of a worker; 1, Honey-crop; 2, Egg-sac; 3, Poison-sac; 4, Oil-gland; 5, Semen-sac or spermatheca; 6, Sting; *c*, Segmental interstices, whence the wax issues. F, Mouth-parts; *a*, Maxillæ; *d*, Basal joint of same; *b*, Labial palpi; *c*, Tongue. G, Bee-louse and its pupa (much enlarged). H, Brush (much enlarged). J, Poison-apparatus; Poison-gland; *b*, Poison-vesicle; *c*, Sting-groove; *a*, Sting; *e*, Sting-sheath. (All much enlarged.)

vacant spaces between. The greater the number of the cells the stronger the colour, the stronger the colour the more numerous the swarms and the greater the chance of the perpetuation of the race. The intermediate form between the cylinder and the regular hexagon is found in the comb of the Melipona bee, which forms cylindrical cells, but so close together that the partition-wall becomes a flat-plate, since it is impossible for a thin sheet to be concave on both sides at once; modifications from this form combined with modified instincts would eventually produce a regular hexagon. It is to be borne in mind, however, that this form arises not because the bees are aware that a regular hexagon is the most economic form of cell they can adopt, but simply because, when a group of bees stand close to each other, and form cells of pliant wax,—whose walls break through at all points on account of their proximity, rendering it necessary to build up a flat wall between,—they cannot fashion it in any other way. For at all points of a single cell, six bees

at the sides, and six bees below are constantly encroaching and fitting in the sides and corners of their own cells, around that of each single bee. Bees have proved in practice what to the mathematicians is inevitable in theory. Nevertheless, bees are not compelled to form their combs in this or that way without any power of adaptation to special circumstances. They construct their comb and hang their connections wherever the holding seems likely to be most secure, and thus, on a less complicated plane of intelligence, carry out precisely what human beings accomplish under more complex conditions, namely, they adapt means to ends. The difference is one of degree, not of kind.

The fact that eggs are laid by a single female of unusual size is noteworthy. Bee-colonies, however, unlike those of the social wasps, are permanent, hibernating during the winter. Each wasp-colony or nest originates from a single female, which survives through the winter and by herself lays the foundation of a new colony. Among bees a certain number of workers, or non-fertile females, are set apart as maids-in-waiting, who attend to the queen's wants in the matter of food, which are considerable during the period of laying. A single egg is laid in each cell, and, as mentioned above, larger cells are set apart for the queens; the difference between these and the non-fertile females being entirely brought about by the difference in food. This, however, is not the case with the males, and it is a disputed point whether the queen can control the sex of any particular egg, or whether she can select a male egg as she proceeds with the laying. Certain it is, at any rate, that when she reaches a drone or male-cell, which is larger, she deposits an egg which will become a male. It has usually been asserted that unfertilised eggs become males, while those which are fertilised turn out females. This may be the case, and certainly would tend to bear out the general truth that absence of nutrition tends to give the male element greater preponderance in the progeny, though the immediate physical conditions on which the sex of the offspring depends are imperfectly known. A superabundance of males is, as a rule, associated with failing provisions and loss of bodily energy, and this is borne out by the fact that when the queen is old she is apt to lay too many drone-eggs. This, however, is a failing which the community cannot put up with, and if the queen be unable to produce profitable offspring she is put to death. Still both bees and queens well know that the one supreme calamity which can befall the bee-community is to be left without a queen, not because they need her rule, but because on her alone rests the future of the colony. And it has been asserted that if two queens only remain, and are contesting for the mastery, and each should simultaneously have the chance to deliver a sting which might prove fatal to both, each releases the other, dreading to leave the hive queenless.

Swarming. Inseparable from these phenomena is that of swarming or the budding off of new colonies from the mother-hive. Owing to the instinct of the workers, who can arrest or accelerate development by regulating the food-supply, a new queen is always ready when a swarm of bees is prepared to leave the overcrowded hive. This queen is, however, not permitted to leave her cell till the actual moment of flight; and all along has to be protected from the reigning queen, by whom, if opportunity were afforded she would be killed. Indeed, when the swarming season is over, the actual sovereign is permitted to

make short work of all her rivals. The function of the nurses, as their name implies, is to rear the young, and, if necessary, preserve the queens. After the males, or drones, have fulfilled their duties, they are massacred in thousands by the workers; even the young grubs and pupæ being dragged from their cells and killed. In many wasp-societies, these matters are, however, more leniently arranged, since the males usually assist in the general duties of the colony. Still even these exhibit an unaccountable habit, all the grubs and pupæ being dragged out and slain as winter approaches. Whether the wasps themselves begin to experience the pinch of hunger, and wish to close mouths which must otherwise starve, or what may be the motive for such action, is beyond our ability to guess. Since every wasp, save here and there a large female, or queen, perishes at the approach of winter, the massacre cannot be justified on the score of prudential social policy.

Solitary Wasps and Mud-Wasps,—Families *Masaridæ* and *Eumenidæ*.

The true wasps may be conveniently divided into solitary and social wasps, although there is a more or less complete transition between the two. Of the typical



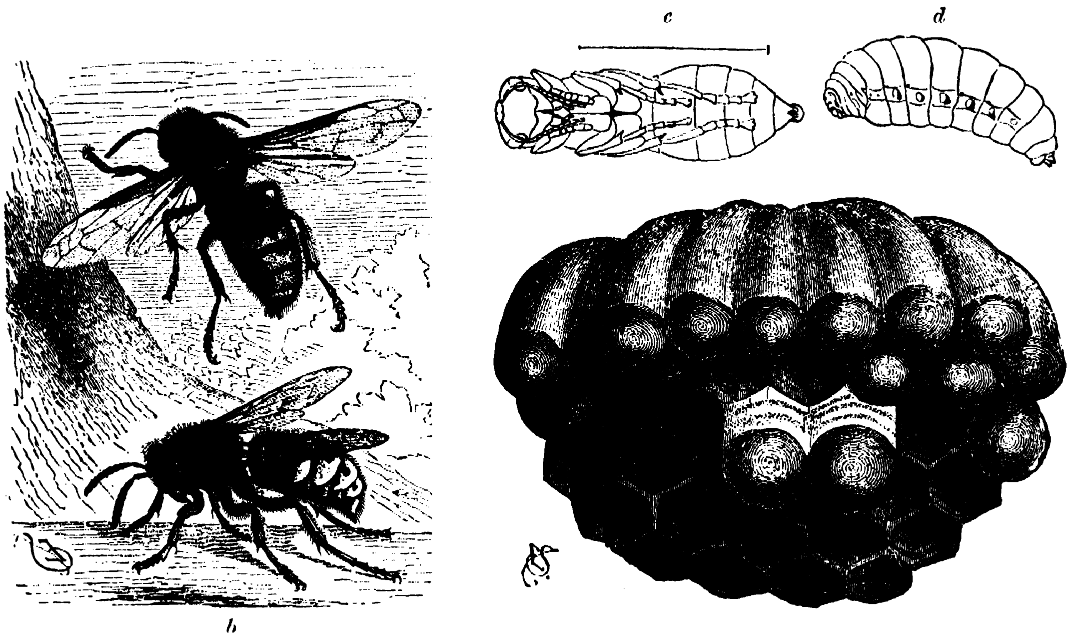
MUD-WASPS.
1, *Odynerus parietum*, female, with nest; 2, *Chrysis ignita*; 3, *Polistes gallica*, female and nest.

solitary wasps (*Masaridæ*), which are mostly tropical forms, and constitute a link between the parasitic wasps described above and the *Vespidæ*, but little is known. Some kinds are, however, parasitic, and possibly many may be so. On the other hand, the *Eumenidæ* are solitary wasps, which make their nests chiefly in mud-walls or sandstone cliffs; some constructing a series of mud-cells in the hollow stems of plants, and supplying their grubs with caterpillars for food. A well-known European example is the figured *Odynerus parietum*, a variable insect, making its appearance in May and June. The nests are made in holes of old mud-walls, or the banks of clay-pits, and are filled with grubs of beetles belonging to the family *Chrysomelidæ*, or with the caterpillars of small moths.

Social Wasps,—Family *Vespidæ*.

The members of this group form a link between the foregoing and the true bees, since each species includes a fertile female or queen, unfertile females or

workers, and males or drones. The nests are formed of a kind of paper manufactured from the dry parings of old posts and trees. Since we have already dealt briefly with the general habits of the *Vespidæ*, further reference to them, save as occasion for their mention arises in the course of subsequent description of species, will be unnecessary. The members of the family may themselves be distinguished at once from all other Hymenoptera by the peculiar arrangement of the wings when folded at rest. The fore-wings partly enclose the hind-wings, both pairs lying along the sides of the abdomen, not concealing it from above. The food of wasps consists of the saccharine matter derived from various vegetable products and also from animal matter. As regards the distribution of species—apart from the usual increase in size and beauty of colouring—it may be remarked that the closer the equatorial regions are approached, the more numerous do members of

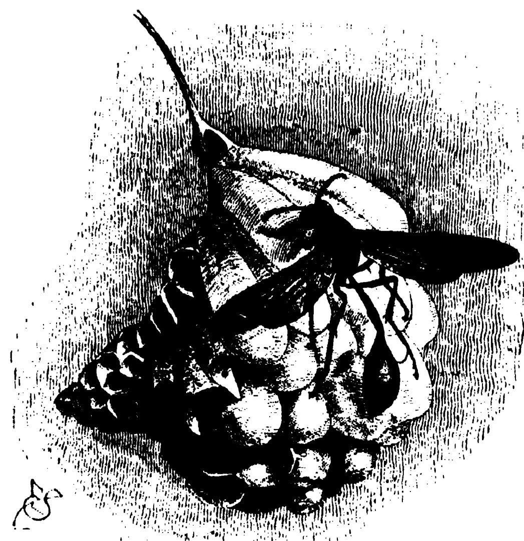


LIFE-HISTORY OF THE HORNET.

a, *b*, Adult; *c*, Portion of brood-cells; *d*, Larva; *e*, Pupa. (*d* and *e* somewhat enlarged.)

this group become. Of the better-known forms the common hornet (*Vespa crabro*) is readily distinguished from other species of wasps by its large size and the prevailing red tint on the anterior portions of the body. It is universally distributed throughout Europe, and occurs as far north as Lapland. The solitary female, after her hibernation, commences to build the first foundation of her nest in May on some convenient beam in a loft or outhouse, or frequently in the holes made in the eaves of thatched cottages by sparrows. The food of the grubs consists of the bodies of insects, bees, etc., which the workers chew up for their benefit. On the approach of autumn the remaining larvæ, which have not yet been hatched out, are torn from their cells and left to perish. Under the title of common wasps no less than five species may be included, although *V. vulgaris* is the common wasp *par excellence*. *V. germanica* may be recognised by the three

black spots on a yellow clypeus. *V. vulgaris* presents a longitudinal black line dilated at the extremity. *V. rufa* is rare in Northern Europe. *V. media* has the yellow markings of the abdomen darker than in the other species. The wood-wasp, *V. silvestris*, hangs its nest on the bough of a tree or shrub. Such brief notices are, of course, wholly inadequate for a student of the group; and reference must be made to writings devoted to the special points of difference between these closely allied species. Among other forms space only admits mention of the South African wasp (*Belonogaster*), of which the comb is shown in the annexed figure. Common in houses at the Cape, this insect is much dreaded on account of the severity of its sting.



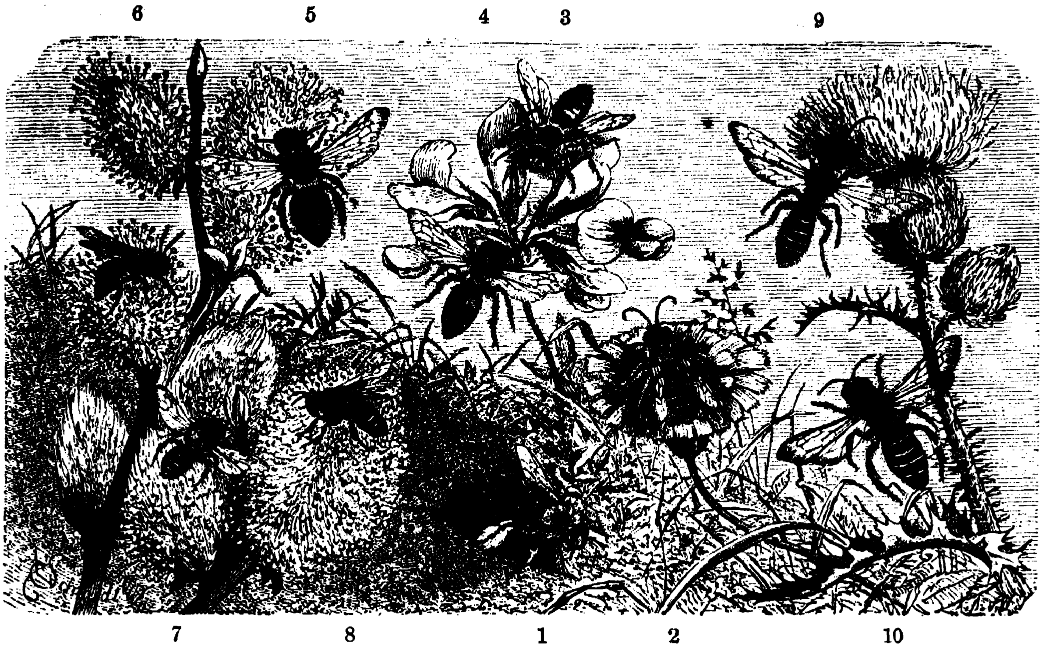
SOUTH AFRICAN WASP AND ITS NEST (nat. size).

SOLITARY BEES,—Family *ANDRENIDÆ*.

These insects may be recognised by the fact that the pollen-collecting organs are situated on the femora and coxæ of the hind-legs, and the neighbouring sides of the thorax. The genera *Andrena* and *Hylæus* comprise the greater part of all the wild bees of Central and Northern Europe. The perfect insects appear in the early spring, making their nests in sandy soil. In the first genus figures of three species (*A. schencki*, *A. cineraria* and *A. fulvicrus*) are given in the accompanying illustration. *H. grandis*, figured on the same illustration, flies in July and August, and forms a large number of holes—a kind of colony—in some sunny slope. The species of both *Andrena* and the allied *Halictus* are parasitic, and display a very curious habit. When retiring to rest they fasten upon a twig or the edge of a leaf with their mandibles, fold their wings, draw up their legs, lay the antennæ neatly along their backs, and, having induced a temporary lock-jaw, hang securely until the morning, when they loose their hold and hurry off once again to play the parasite on their relatives. Another species figured in the same illustration is the hairy-legged bee (*Dasypoda hirtipes*), which appears on the wing in July, and constructs a nest of about six cells in sandy ground. The burrow runs obliquely at first, afterwards descending perpendicularly. Another well-known type of the family is exemplified by the mason-bees, of which one species (*Chalicodoma muraria*) is represented in the annexed illustration. These insects make their appearance in Europe during May, when the female forthwith sets about constructing her nest. This includes not more than ten simple cells, and is attached to old walls or houses; the cells being formed of grains of sand glued together with the saliva of the builder. In 1886 some bees of an allied genus (*Osmia*) constructed their nests in the locks of a door at Deptford. The cells had completely choked the works of the locks, and in one case a portion of the nest was forced out by the insertion of the key without driving away the bees.

As the locks were in pretty constant use, it would appear that all the nests must have been built within a few days.

The leaf-cutter bees, of which an example (*Megachile centuncularis*) is figured on the illustration on p. 36, take their name from lining their nests with cells



GROUP OF SOLITARY BEES.

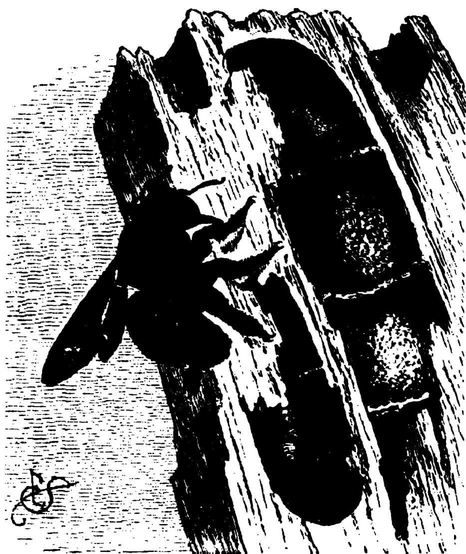
1, 2, Hairy-legged bee (*Dasypoda hirtipes*); 3, 4, Shenck's earth-bee (*Andrena schencki*); 5, 6, Grey-haired earth-bee (*Andrena cineraria*); 7, 8, Brown earth-bee (*A. fulvicrus*); 9, 10, Large burrowing bee (*Hylæus grandis*). A male and female of each is figured. (All of nat. size.)

made from fragments of leaves nipped out by the strong jaws of the insects. These cells may be placed either in the holes of trees, in clefts and crannies of old walls, or in specially constructed burrows in the ground. Among the leaves most generally employed are those of the poplar, hornbeam, privet, poppy, and rose. The mode in which these insects work, and the structure of their cells and burrows are exhibited in the illustration. Yet another type of building is exemplified by the carpenter-bees (*Xylocopa*), which are amongst the finest members of the entire family.



MASON-BEE.

1, Nest with bee emerging and larva in an open cell; 2, Male; 3, Females fighting. (Nat. size.)



VIOLET-WINGED CARPENTER-BEE, WITH CELLS CUT OUT IN A TREE-STEM.

Their cells are built in rows in the solid wood of trees, and the method of procedure will be observed in the illustration exhibiting the violet carpenter-bee (*X. violacea*). This species, which is rare in Northern Europe, forms a series of cells in each of which lies a larva, and since the lower ones are obviously the oldest, it is somewhat difficult to understand how the newly-emerged perfect bee escapes into the upper air from the lower cell. At present it is not altogether clear what course it takes; whether it gnaws its way through the chambers where brothers and sisters are peacefully awaiting future developments—at the imminent risk of arresting all chances of such by thus breaking into their bedrooms, to the detriment of nervous systems not yet hardened to bear the strain—or whether it gnaws its way straight out at the side, seems a matter of doubt. Some authorities state that the female has already foreseen and guarded against such undesirable contingencies, by preparing a door of escape at the bottom of the lower cell. And they record as a remarkable fact that the bees, each in turn, gnaw through the floor of its cell, and of course find their elder brother or sister already flown from the cell next below. They never go in the opposite direction through



1, 2, HAIRY-LEGGED FLOWER-BEE (*Anthophora hirsuta*), female and male. 3, 4, TUFTED FLOWER-BEE (*A. retusa*), female and male; 5, WALL-NESTING FLOWER-BEE (*A. parietina*), female; 6, 7, LONG-HORNED BEE (*Eucera longicornis*), female and male. (All of nat. size.)

the roof. Our next examples of this family are the flower-bees (*Anthophora*), of which three species are shown in the annexed illustration. In general appearance these insects closely approximate to humble-bees. They build their nests in

burrows in the ground, in holes of trees, or clefts and cracks in walls; the cells being separated by partitions, and made of the ruins of the burrow or cleft. Generally the whole nest has the form of a twisted tube. Like their allies, these bees are solitary, and, like humble-bees, are much infested by parasites. Finally, we have the long-horned bees, of which one species (*Eucera longicornis*) is shown in the same illustration. These bees construct smooth tunnels in the earth, divided as usual into sections, each of which contains one egg, together with a supply of pollen and honey for the future larva.

TRUE BEES,—Family *APIDÆ*.

In this group are included not only the various kinds of honey-bees, but likewise their more clumsy cousins the humble-bees. Such a well-known insect as the common honey-bee (*Apis melifica*), of which the habits have been already referred to, requires no special notice; but it is important to observe that the



1, COMMON HUMBLE-BEE WITH NEST; 2, STONE HUMBLE-BEE. (Nat. size.)

honey-bees of the equatorial zone differ somewhat from those inhabiting more temperate regions, in consequence of which they are assigned to distinct genera, such as *Melipoma*, *Trigona*, and *Tetrasoma*. All these are rather small and stingless bees, making up for the absence of a special weapon of offence by a free use of their jaws. Their brood-cells and combs resemble those of the common wasp, each forming but a single layer; and clay and resinous substances being chiefly used for closing the entrance of the cavities in which the nest are placed. The characteristic transitional features in the shape of the cells, intermediate between the simple cylindrical and the perfect hexagonal forms, have already been noticed in the short introductory remarks. *Melipoma* and its allies form the connecting link between the solitary and the hive-bees. As in the wasps, each family in the humble-bees owes its origin to a single female which has hibernated—usually in

some hole in the ground which it excavates for the purpose. The hive-bees, on the contrary, swarm, that is, they send off a full-grown population under a queen ready to enter upon the organised life of an industrial community at once. The different forms of humble-bees are much the same as those of the hive-bees, namely, large females; workers or undeveloped females; small females which are similar to the large (or queens) in structure; and males. One very strange habit has been recorded and confirmed by subsequent observations. A small female is set apart for the duty of awakening the nest every morning with her piercing note, and has been called the "trumpeter." It seems that only those nests which are large and have plenty of spare hands can afford this luxury.

Humble-bees, both as regards appearance and habits, are too well known to need description. Of the two species figured in the annexed illustration, the common humble-bee (*Bombus terrestris*) forms small rounded nests of carded moss. On the other hand, the stone humble-bee (*B. lapidarius*) makes its habitation in cavities among stones, where it forms an oval nest, of which only the sides are covered with moss and grass.

F. O. PICKARD-CAMBRIDGE.

[NOTE.—The first ten pages of this chapter are by Mr. POCOCK.]

CHAPTER II.

JOINTED ANIMALS,—*continued.*

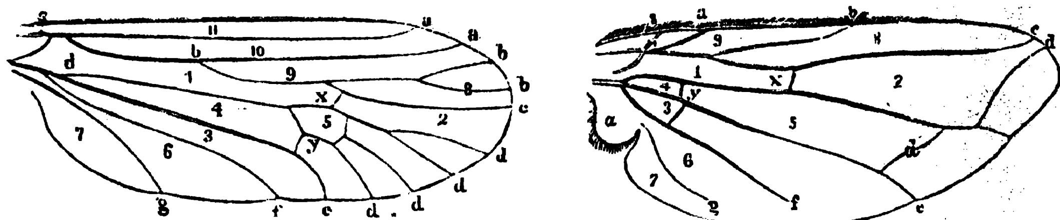
INSECTS,—*continued.*

THE FLIES AND FLEAS,—Order DIPTERA,

As implied by their scientific name, the typical members of the order now claiming attention are distinguished from all other insects by the possession of but a single pair of wings. In this case one pair of these organs has disappeared, and examination will reveal the fact that it is the front pair that is retained in full functional importance, while the hinder pair has become reduced to a couple of short slender club-like organs, known as *halteres* or balancers. From their small size it might be supposed that these balancers were organs of but little physiological importance, but the experiment of removing them will show that this is not the case; for an insect thus mutilated is thereby entirely deprived of the power of maintaining its equilibrium and of directing its course in the air. Hence the name balancers that has been assigned to these rudimentary wings. The mouth-parts, instead of being of the primitive mandibulate type, are formed for purposes of piercing or sucking. In the former kind of structure, as represented for instance in *Pangonia longirostris*, one of the horse-flies (*Tabanidæ*), these organs are composed of seven pieces, which have been interpreted by Mr. Waterhouse as follows. The uppermost is a long pointed instrument, the labrum. Immediately below this, and more or less concealed by it, is an almost equally long and slender piece, which is probably the hypopharynx. The mandibles are modified into a pair of sharp lancets, and below them are two extremely slender instruments, which, from the presence of palpi, are recognisable as parts of the maxilla. All these pieces lie concealed in the basal half of the proboscis, which, for part of its length, is gutter-shaped, but afterwards assumes the form of a tube, and is believed to be comparable to the labium. In the gnats the mouth is formed upon the same plan, but the lancets are all more slender. In piercing the skin the lancets only are used, the labium or proboscis serving merely as a guide. In the flies that use the mouth for sucking—as for instance in the blow-flies and drone-flies—the jaws are still more modified, so that the identity of the separate pieces is difficult to establish. The most prominent part is the proboscis, the expanding terminal lobes of which are the *paraglossæ* of the labium. The maxillæ are represented by two scales or short stylets closely adherent to the sides of the proboscis, and of two club-like palpi; but the mandibles seem to have disappeared.

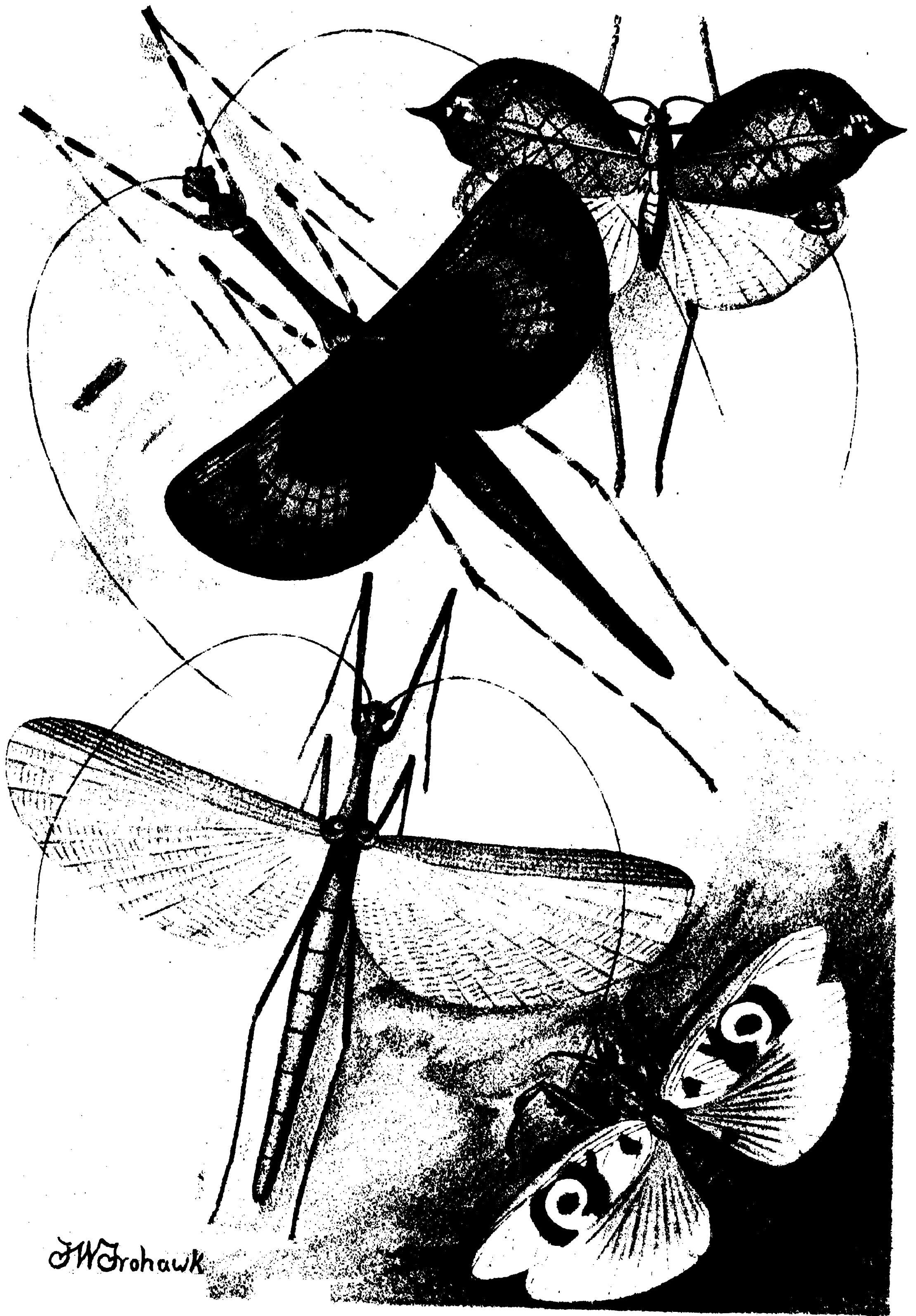
The only character that need be specially noticed in the wings is that they are usually naked,—being but rarely furnished with short hairs,—and that the veins

are almost all longitudinal, that is, they run from the base or point of attachment of the wing to its free margin. These veins are represented in the accompanying figures by the letters *a*, *b*, *c*, *d*, *e*, *f*, *g*. The transverse veins *x*, *y*, on the contrary, are always few in number. The shape and size of the spaces (indicated by the numbers 1, 2, 3, etc.) circumscribed by these veins form valuable systematic characters for distinguishing the species and genera of this order. The balancers may be entirely exposed, as in the common daddy-longlegs, but are sometimes concealed by a scale-like membrane as in the blue-bottle fly. In connection with the wings may be noticed the buzzing of flies. This appears to be the result of two distinct sounds, one produced by the rapid vibration of the wings, and the other by the vibration of the thorax. The latter movement is the more rapid of the two, and gives rise to the shrill note heard the moment a blow-fly is seized; while the former is the ordinary buzzing produced when the insect is in flight. According to recent calculations, the thoracic vibrations in the case of one of the humble-bee flies (*Volucella*) amounted to thirteen hundred per second, while those of the wings were just one-half this number, namely, six hundred and fifty per second. The legs possess the normal five segments; the tarsi or feet, which are



WING OF DADDY-LONGLEGS AND OF BLOW-FLY.

also divided into five segments, being armed with two claws, and in addition, often supplied with adhesive pads, by means of which the insects are enabled to ascend perfectly smooth surfaces. These pads are composed of a multitude of funnel-shaped hairs, each supposed to act as a minute sucker. Some authors assert, however, that they secrete a sticky fluid, and that the insect maintains its hold by this means. The antennæ vary considerably in structure. In their least modified form, as presented by the gnats and their allies, they are simple and thread-like organs, consisting of a series of subequal segments, often modified by the presence of long symmetrically arranged bristles, which impart to them a feather-like aspect. In most of the members of the order the antennæ are, however, curiously constructed. The three basal segments are stout, the third being especially large and produced into a great lobe-like plate, sometimes projecting as far as the extremity of the terminal part of the organ, which frequently has the form of a plume-like whip, the *flagellum*, although sometimes reduced to a bristle. Not unfrequently the antennæ differ greatly in structure according to sex. In the males of gnats, for example, they are large and feathery, while in the females they are only furnished with short hairs. The males and females of most of the common flies, on the contrary, may be recognised by the development of the compound eyes. In the former sex these organs are almost in contact on the summit of the head, while in the latter there is a widish space between them. Rarely the sexual characters are



ORTHOPTERA

much more pronounced, as for instance in the stag-horned flies, in which the head of the male is furnished with large branching processes, and the stalk-eyed flies, in which the eyes in this sex are supported upon long, horizontal, immovable stalks.

Like the other higher orders of insects, flies, in the course of their development, go through a complete metamorphosis; the larvæ—of which perhaps the commonest are maggots and cheese-hoppers—being worm-like, and passing into a partially or wholly quiescent pupal stage before attaining maturity. These larvæ differ much in structure in some of the families; those of the gnats having a well-developed head, with the antennæ, mandibles, maxillæ, and labium always recognisable; whereas in the maggots of the blow-fly the head is narrow and pointed, without antennæ, and with the mouth-parts reduced to a pair of retractile hooks, the opposite extremity of the body being broad and square-cut. It must not be supposed, however, that the larvæ of all the members of this order are of one or other of these two types. On the contrary, the structure varies according to habitat, and almost every gradation is found linking the two together. Some species live in fresh-water ponds and streams, others in the earth amongst roots of grass, others again in rotting animal or vegetable matter, and others, like the maggots of the warble-fly, in the stomachs of the hosts they infest. Thus the nature of their food and surroundings is extremely varied, and that the larvæ are likewise so, may be seen by a glance at the figures in the following pages.

Upon reaching its full size the larva passes into the pupal stage. The pupa, however, exists under two conditions. In one case, as in the gnats, it emerges from the skin of the larva and leads an independent life of longer or shorter duration, until the attainment of maturity; in the others, as in the fly called *Stratiomys*, it remains within the larval skin, which becomes thickened and constitutes a protective covering for it. Again, the rupture of the larval skin for setting free the pupa is effected in one of two ways. In the first case the opening is T-shaped, consisting of a longitudinal split on the back behind the head, or rarely of a transverse split between the seventh and eighth segments of the body; in the second case a circular split occurs behind the head, which is pushed off like a kind of cap. These two methods of splitting of the larval skin have been used as characters for dividing the Diptera into two suborders, those in which the pupa escapes in the former way being termed straight-seamed flies, or Orthorrhapha, and those in which the pupa escapes in the latter way circular-seamed flies, or Cyclorrhapha. For the rupture of the larval skin, the pupæ of the Cyclorrhapha are furnished with a bladder-shaped excrescence on the front of the head. In the vast majority of flies the young make their first appearance in the form of eggs. In some few cases, however, as in the genera *Sarcophaga* and *Mesembrina*, belonging to the family *Muscidæ*, the young are born as active maggots; while in the forest-flies and their allies only one young one matures at a time, and this is retained by the mother and nourished at her expense until it has passed into the pupal stage. The most anomalous method of reproduction occurs in one of the gall-midges, where the larvæ themselves produce other grubs by a process of internal budding.

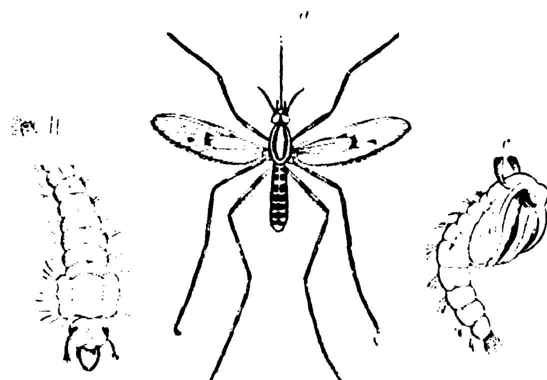
That flies were abundant in early Tertiary times, when they were not very different from those that now exist, is shown by the abundance of their remains preserved in the amber beds of the Baltic. Strata of the same age at Florissant,

Colorado, have also yielded fossil flies. A few have been obtained from Secondary rocks.

THE STRAIGHT-SEAMED FLIES,—Suborder **Orthorrhapha.**

The first section of this suborder contains the gnats and mosquitoes (*Culicidæ*), daddy-longlegs (*Tipulidæ*), true midges (*Chironomidæ*), and fungus-midges (*Mycetophilidæ*). These families are sometimes spoken of collectively as the Nematocera, or flies with thread-like antennæ, on account of the length and thinness of those organs, which usually consist of as many as ten or more segments. The maxillary palpi also are elongate, and the body and limbs present, as a rule, the type with which we are familiar in the gnats and daddy-longlegs.

Mosquitoes and Gnats. The mosquitoes and gnats (*Culicidæ*), although often regarded as distinct, are in reality identical. They abound in all lands, and may be met with in cold barren countries like Iceland and Lapland as well as in the dense forests of tropical climes, everywhere being the plague of travellers on account of their insatiable thirst for blood and the intense irritation caused by their bite. It is, however, only the females that bite and suck blood, and in this connection it may be pointed out that no members of the Diptera sting in the sense in which the word is used with regard to ants and wasps; that is to say, the wound, although giving rise to a sharp stinging sensation, is inflicted by jaws, and not, as in the case of the ants, by an organ especially designed for the purpose placed at the hinder extremity of the abdomen. The annexed figure representing the banded gnat (*Culex annulatus*), a species sometimes found in houses, and noticeable for being the largest British form, is selected to illustrate the mode of life characteristic of the members of this family. The long slender eggs, amounting to some three hundred or more, laid by the mother in batches on the surface of a pond or ditch, give rise to worm-like larvæ furnished with a distinct head, a large somewhat squared thorax, and a tapering jointed abdomen. Along each side of the body there is a row of bristle-tufts, one for each segment, and the last segment is in addition produced into a couple of tubular tails, at the extremity of which open the tracheæ or breathing-tubes. Thus equipped, the young gnat hangs suspended in the water, its heavy head directed downwards, and the tip of its forked tail just projecting above the surface, so that the apertures of its breathing-apparatus are in communication with the air. Occasionally when the surface of the water is disturbed, or from any other reason causing alarm, the larva wriggles to the bottom of the pond, soon, however, to return to its accustomed place at the surface. During growth, the larva undergoes a series of three moults before reaching its full size, the newly-clothed insect escaping


BANDED GNAT.
a, Female; *b*, Larva; *c*, Pupa. (All enlarged.)

from the old skin through a longitudinal slit behind the head. At the fourth moult emerges the pupa, which is a very different looking creature from the larva, showing the cases for the antennæ, wings, and legs of the adult, while from the sides of its thorax project a pair of tubes, analogous to those of the larval tail, and like these carrying the apertures of the tracheæ. By means of its jointed abdomen the pupa jerks itself about in the water in company with others of its kind. At the appointed time a longitudinal split occurs on the back behind the head, and, extricating itself from its pupal-case, the adult gnat appears on the surface of the water, where under favourable conditions its skin hardens and its wings unfold, while it floats upon the water using its discarded clothing as a raft. If this time of danger be successfully overcome, the insect takes wing and joins its companions in their mazy dance; but, before acquiring strength to do so, it is at the mercy of every wave or gust of wind, and if once swept back into the water, its chances of survival are small. The above-mentioned banded gnat may be distinguished from other British species by its large size, its spotted wings, and striped legs and abdomen. The common gnat (*C. pipiens*), which is often abundant in houses in the autumn, is much smaller and without the ornaments characteristic of its larger ally.

Travellers in the tropics are so familiar with mosquitoes that nothing we can say can add to their knowledge of the subject. But to give those who have been fortunate enough to avoid a practical acquaintance with them some idea of the torments caused by these little pests, we quote the following passages from the works of two well-known naturalists. Speaking of his sojourn at a place on the Amazons, Bates says "at night it was quite impossible to sleep for mosquitoes; they fell upon us by myriads, and without much piping came straight at our faces as thick as rain-drops in a shower. The men crowded into the cabins and then tried to expel the pests by the smoke from burnt rags, but it was of little avail, although we were half suffocated by the operation." Again, Emerson Tennent writes that "of all the insect pests that beset an unseasoned European, the most provoking by far are the truculent mosquitoes. Even in the midst of endurance of their onslaughts one cannot but be amused by the ingenuity of their movements; as if aware of the risk incident to an open assault a favourite mode of attack is, when concealed by a table, to assault the ankles through the meshes of the stocking, or the knees which are ineffectually protected by a fold of Russian duck. When you are reading, a mosquito will rarely settle upon that portion of your hand which is within range of your eyes, but cunningly stealing by the under side of the book, fastens on the wrist or little finger and noiselessly inserts his proboscis there. I have tested the classical expedient recorded by Herodotus, who states that the fishermen inhabiting the fens of Egypt cover their beds with their nets, knowing that the mosquitoes, although they bite through linen robes, will not venture through a net. But notwithstanding the opinion of Spence, that nets with meshes an inch square will effectually exclude them, I have been satisfied by painful experience that, if the theory is not altogether fallacious, at least the modern mosquitoes of Ceylon are uninfluenced by the same considerations which restrained those of the Nile under the successors of Cambyses." An interesting question arises in connection with mosquitoes as to the nature of

the food of the vast hordes of them that frequent the tropics. It is true that the females alone bite; but the proboscis is a highly perfected organ for piercing and sucking, and it might be supposed that it is extensively used for the purpose. Yet it has been pointed out that the vast majority of mosquitoes can never taste mammalian blood. In various places, such as parts of India for example, mosquitoes are found in swarms in spots never visited by human beings, and in which there are no large mammals. It has been suggested that, failing to obtain blood, mosquitoes support themselves on the juices of plants, but no observations in support of this have been recorded.

Daddy Long-Legs.

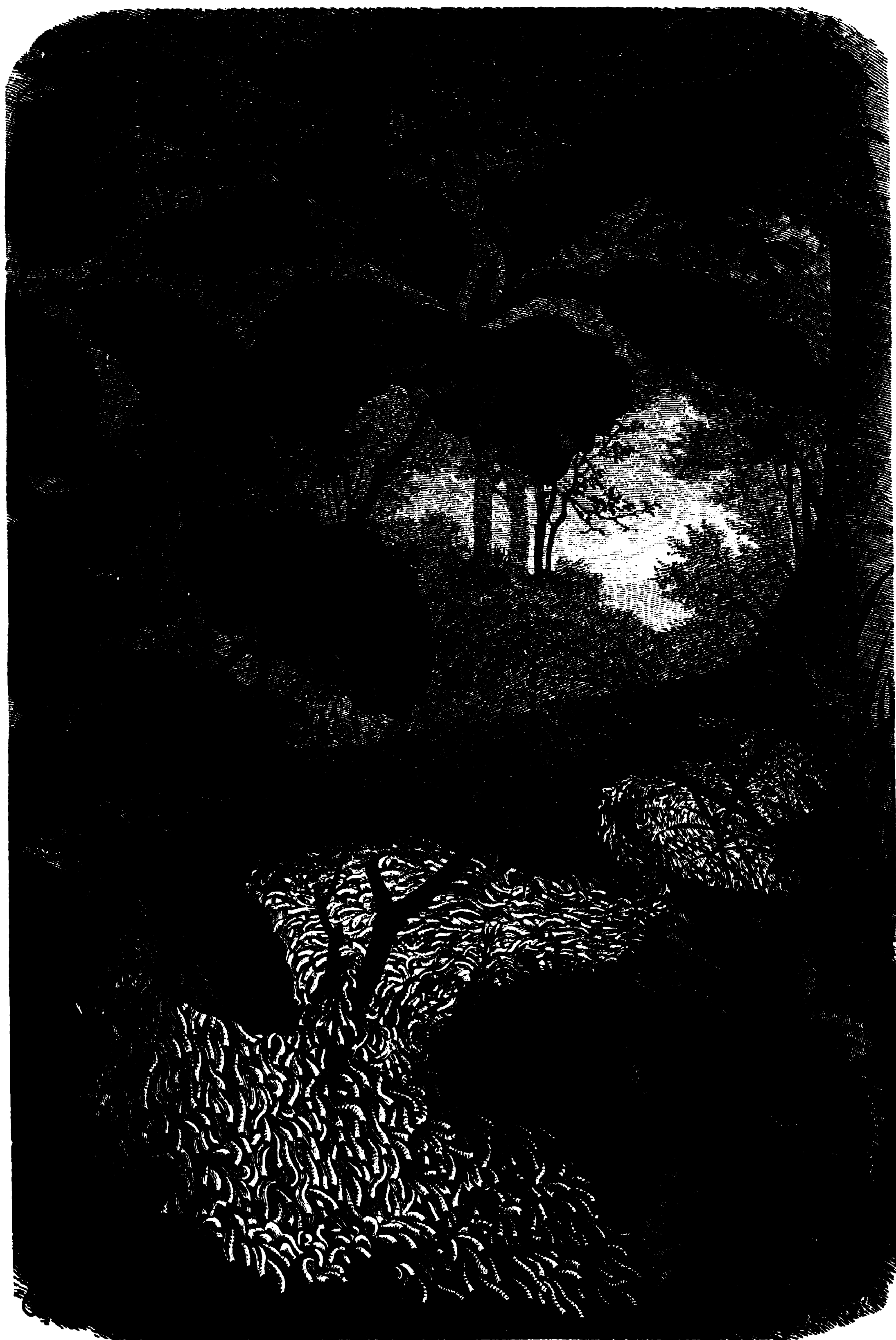
The daddy long-legs (*Tipulidæ*) contain the finest species of this division of the order; the largest European form being the giant daddy long-legs (*Tipula gigantea*), which has its wings clouded with brown, and measures about 1¼ inches in length. Much larger kinds are, however, met with in Burma and China. The short and fleshy proboscis is not adapted for piercing, but merely for absorbing fluids; and the antennæ are not feathery, as is so often the case in the gnats and midges, although in the species of the genus *Ctenophora*—which are of stouter build, and often brightly coloured black and yellow, thereby resembling some of the saw-flies—the antennæ are pectinated in the male. In this family the eggs are laid and the larvæ undergo their growth and change of form either in water or earth. The females of two of the commonest British species (*T. oleracea* and *T. paludosa*) may be seen in summer and autumn flying about meadows and depositing their eggs here and there in the soil. When hatched, the larvæ start feeding upon the roots of grass and corn, thereby doing considerable damage to farmers and gardeners, to whom they are known by the name, "leather-jackets."

Midges.

The true midges belonging to the family *Chironomidæ* are nearly allied to the gnats, with which they are often confounded; but the mouth-parts are rarely adapted for piercing, the proboscis being short and soft. In the genus *Ceratopogon* the jaws of the females are, however, lancet-shaped, and capable of drawing blood. The little black midge that in the summer settles upon the hands and face and inflicts a sharp prick belongs to this genus. But the best known member of the family is the plumed midge (*Chironomus plumosus*), which on summer evenings may be seen dancing in swarms along roads and lanes. Its name has been given to this species on account of the beautiful feathery-like antennæ of the male. In connection with this species a case of luminosity has recently been recorded. An observer in Russian Asia found on the shores of Lake Issykkul a number of examples of this midge, and of an allied form belonging to the genus *Corethra* emitting a phosphorescent light. Failing to discover any luminous organ he came to the conclusion that the light was due to the presence in the insect of multitudes of parasitic bacteria, an opinion strengthened by the observation that the shining individuals were sluggish and never seen on the wing.

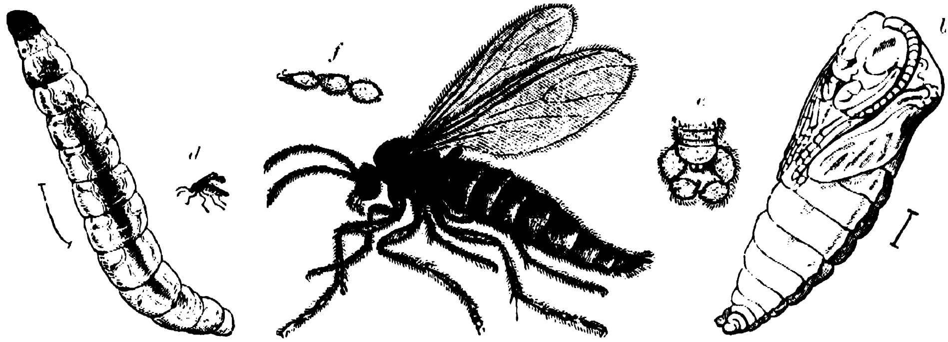
Fungus-Midges.

The fungus-midges (*Mycetophilidæ*) take their name from the fact that the larvæ of most species feed upon fungi of various kinds. The perfect insects, which frequent damp situations, are all of small size, and mostly pale in colour. To this family belongs the so-called yellow-fever fly, a species of the



A COLUMN OF THE ARMY-WORM.

genus *Sciara*, which in North America is said to appear when yellow fever is prevalent. But perhaps the most notorious species is the so-called army-worm fly (*Sciara militaris*), which has long attracted attention on account of the peculiar habits of the larvæ. This fly is completely black, with the exception of its legs, which are brownish. The female, which is represented of the natural size at *d*, in the accompanying illustration, and enlarged at *c*, is larger than the male, and has the abdomen terminating in a pointed stylet. In the male, on the contrary, there is at the apex of the abdomen a pair of thick two-jointed claspers, and between these a couple of small adjacent processes, as shown at *e*. The extremely small eggs are laid by the mother, to the number of about one hundred, upon soil amongst fallen leaves on which the larvæ feed. On attaining maturity, these larvæ measure nearly a quarter of an inch long, and have the form represented at *a*. The black head is distinct, and furnished with eyes, and the semi-transparent body consists of thirteen segments, some of which are furnished with lateral black stigmata. In many countries of Europe where this insect is met with, vast hosts of these maggots, forming a compact mass, sometimes several feet long and an inch



ARMY-WORM FLY (*Sciara militaris*).
a, Larva; *b*, Pupa; *c*, Female midge; *d*, The same (nat. size); *e*, End of abdomen of male; *f*, A portion of the antennæ. (Magnified, except *d*.)

or two broad, have been seen at times creeping along at a slow pace through the woods like a greyish serpent. The maggots crawl along, not only side by side, but also one over the other, all adhering together by their sticky surfaces, and continually changing their position in the column. At the close of their march, when fatigue or want of nourishment causes them to rest for a time, the larvæ composing a single train collect into a ball, which gradually diminishes in size, and finally disappears by the burrowing into the mould of those that are lowest in the mass. For a long while the reason for this peculiar habit remained wrapt in obscurity, and perhaps even yet we do not understand its full significance. It has been suggested, however, that when the supply of food for the multitude runs short, the whole army is moved by a sudden impulse to start in search of fresh supplies. It is almost superfluous to add that the peasantry of the countries where this strange phenomenon is observable, failing to understand its true significance, have from time immemorial regarded it as something supernatural, and as foretelling various events in the future, some looking upon it as a sign of the imminence of war, others of the destruction of their crops, and so forth. The pupa of the army-worm is

shown at *b* in the figure on p. 55. This stage lasts from eight to twelve days; but the perfect insect is shortlived, the female surviving apparently only long enough to pair with the male and lay her eggs.

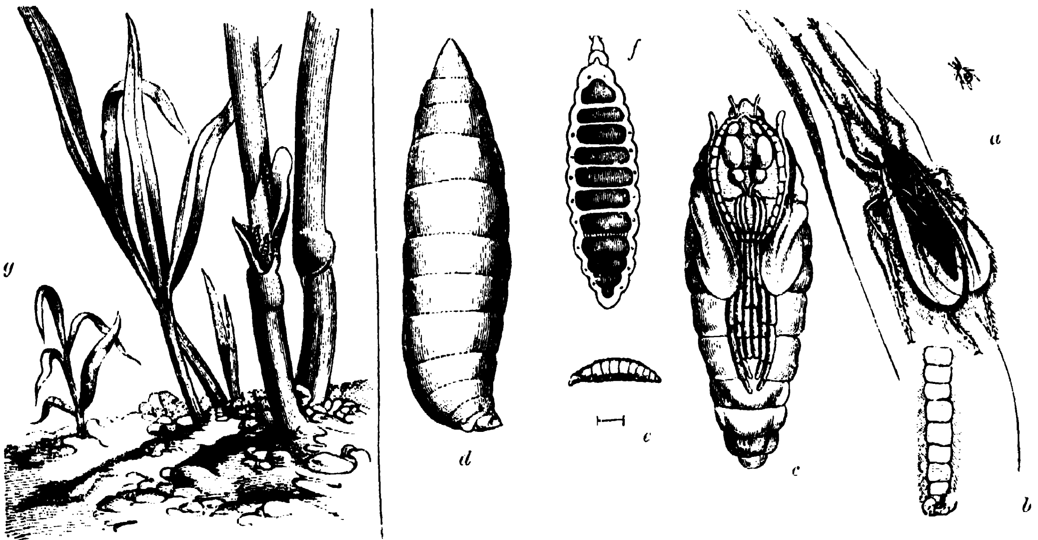
When speaking of one of the true midges reference was made to a pathological case of phosphorescence, but in the present family there are two instances known of the normal occurrence of this phenomenon—not, however, in the adult insect, but in the larval or pupal stages. The first instance is furnished by *Ceroplatus sesioides*, a midge, which although not yet known to occur in England, has been met with in several of the countries of Europe. Here the luminosity is said to resemble that of the glow-worm, but proceeds from the entire animal, and from members of both sexes. The larvæ, which are found in small colonies on the under side of a fungus, exhibit, when crawling in the dark, a moving streak of light, less bright than that emitted by the pupæ. The insect also shines when lying in the cocoon, so long as its abdominal rings are still transparent and have not attained their complete colouring. The cocoons themselves are not luminous, but allow the light to be transmitted as through a paper lantern; and since as a rule several of them are situated together a more extensive glow is displayed, whereby both the cocoons themselves and the surrounding objects are illuminated. When the insect is about to emerge from the cocoon, the luminosity gradually diminishes, and ultimately ceases altogether. The second instance is presented by a New Zealand midge called *Boletophila luminosa*, the larva of which is known as the "glow-worm." Here the female is luminous in all three stages of its existence, but in the male the luminosity disappears two or three days before the emergence of the perfect insect. The luminous organ, which is situated in the posterior part of the body of the larva, consists of a gelatinous, semi-transparent structure, capable of extension, contraction, and other changes of form, and, like its luminosity, is completely under the animal's control. As to the part played by this organ in the midge's economy, authors are at variance; one believing that the light serves to attract small creatures, so that they become entangled in a web of mucus, which the larva suspends in some niche in the soil.

Gall-Midges.

The gall-midges (*Cecidomyidæ*) are minute, fragile insects, in which the wings are furnished with few veins, are often hairy, and always fringed on the edges. From an agricultural point of view, these insects are the most important of all the gnat-like flies, since much damage is at times done to crops by their larvæ. The most notorious is the Hessian fly (*Cecidomyia destructor*), represented in its various stages in the accompanying illustration. This insect was believed to have been introduced into North America by the Hessian troops at the time of the War of Independence, whence the inhabitants of the United States gave it the name by which it is now commonly known. The adult female, which measures rather less than a tenth of an inch, is mostly of a velvety black colour, varied with blood-red, especially on the abdomen; while the rather larger male is browner, with the red clearer. These flies may be observed on the wing during the second half of April. They live, however, only for a few days, and perish soon after laying their eggs, which amount to about eighty or a hundred. These are placed separately or in pairs upon the leaves of the wheat-plant, and in a short time hatch, when the larvæ crawl down the leaf, reach the stalk, and burrow in it to take

up their abode and feed upon its tissues. This does not immediately, nor in a direct manner, cause the death of the plant, but, weakening its stem, renders it liable to be beaten down by wind or rain, and causes it to bear inferior corn if it reach maturity. Towards the end of July the larvæ are full grown, and pass into the pupal stage; while at the end of August or the beginning of September the adults again appear and lay their eggs on winter wheat, the larvæ that are hatched from these passing the winter in the pupal state and completing their development in the spring. Nearly allied is the wheat-midge (*C. tritici*), which, as its name indicates, also attacks the wheat-plant, to which it at times does great damage. The female lays her eggs—often in numbers—not on the leaves or stems, but in the heart of the blossom, and their presence either entirely prevents the formation of any seed, or renders that produced of a poor kind.

There are many other species of gall-midges which attack different kinds of plants, such as the willow, hawthorn, etc but lack of space forbids further refer-



DEVELOPMENT OF HESSIAN FLY.

a, Female enlarged and of natural size; *b*, Abdomen of male; *c*, Pupa; *d*, Skin of larva forming pupa-case; *e*, Larva seen in profile (the line representing its nat. size); *f*, Larva from above (enlarged); *g*, Wheat-stalks infested with larvæ.

ence to them. One only (*Miastor metroloas*) demands attention on account of the remarkable powers of reproduction of its larvæ. In the majority of cases insects are only able to reproduce their kind after attaining the adult state, the larvæ being merely the young modified for a free and active existence; but the larvæ of this midge, which are found under the bark of trees, possess the remarkable power of producing within their bodies living young. These grow to a certain size at the expense of their parent, whose vitals they devour, then rupture the empty skin and start life on their own account. The second larvæ repeat the same process of reproduction, and so the phenomenon continues through the cold months of the year. At the beginning of the summer the process comes to an end, and the larvæ fulfil their destiny and give rise to mature insects in the ordinary manner.

Sand-Flies, etc. The two families now to be mentioned have been termed the anomalous, or fly-like Nematocera, since although their antennæ are many-jointed, they are shorter than in the foregoing families, and their limbs and bodies instead of presenting the aspect of those of the gnats and midges, are shorter, thicker, and closely approach in this respect those of ordinary flies. To the family *Simuliidæ* belong the minute "sand-flies" of the tropics, which surpass even the mosquitoes in their venomous bite, and on account of their minute size are far more difficult to cope with. In these insects the mouth-parts are adapted for piercing; and the early stages of life are passed in water. The best known European example is the Columbatsch fly (*Simulia columbatzensis*), taking its name from a village in Servia, where it is a great pest. In fact, in all the countries irrigated by the lower waters of the Danube, this fly, hardly larger than a flea, abounds; and it is said that in Hungary cattle and sheep have been destroyed by hundreds owing to the tortures they have suffered from these insects. The little flies creep into the eyes, nose, and ears of their victims, and there gorge themselves with blood, driving the poor beasts to the verge of madness by the intolerable irritation of their bites.



COLUMBATSCH FLY (enlarged).

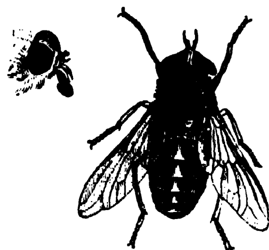
The second family of the group (*Bibionidæ*) contains the well-known St. Mark's fly (*Bibio marci*), a large, black, hairy, slow-flying insect, common in spring, and taking its name from its being frequently seen in numbers on or about St. Mark's Day. The two sexes differ greatly in many respects, the male having the wings clear, whereas those of the female are dusky; again the eyes in the male are so large that the entire head seems to be composed of them, but in the female these organs are small and wide apart. This distinction, however, although not usually in so pronounced a form, is observed between the two sexes of many flies. The eggs—in number amounting to about one hundred and fifty—are laid on the ground among vegetable or animal débris, on which the larvæ subsequently feed. In the grub the head has neither eyes nor recognisable antennæ, but the mouth-parts are distinct; the body consisting of twelve segments, each of which is surmounted by a row of bristles. After passing the winter in the soil in an immature state, the larvæ ascend to the surface in the spring, and take on the pupal stage, from which, after about a fortnight's time, the perfect insects emerge.



T. MARK'S FLY (nat. size, with enlarged figure of larva and pupa).

Horse-Flies, or Breeze-Flies. Although related to the gnats and midges by the nature of the slit through which the pupa makes its escape from the larval skin, and consequently referred to the section Orthorrhapha, the flies of this family approach those of the second section in the shortness of their antennæ, and since all the Diptera with short antennæ were formerly termed the Brachycera,—as

opposed to Nematocera,—these and the remaining families of the suborder are often grouped together as Orthorrhapha Brachycera. Although the horse-flies (*Tabanidæ*) are often termed gad-flies, the latter name is proved by Anglo-Saxon literature to have been originally applied to the *Œstrus*-group of the *Muscidæ*. Horse-flies are distributed all over the world, and vary but little in outward form, usually having large, fat bodies, and being generally of a dull reddish brown colour. They are all bloodsuckers, and the mouth-parts—which have been described at the commencement of the chapter—attain a high degree of perfection as piercing instruments. A common representative of the family in England is the so-called clegg (*Hæmatopota pluvialis*), a greyish insect which has a habit of pitching quietly upon the hands or face, and inflicting a sharp prick almost before the victim is aware of its presence. Fortunately, however, it is easily killed, for, instead of taking flight, it generally stays where it has settled, and allows itself to be crushed. A larger, though scarcer British species is the great horse-fly (*Tabanus bovinus*), the female of which sucks the blood of large mammals, such as horses, asses, and cattle. The males always frequent flowers; and the larvæ in form and habits show considerable resemblance to those of the daddy-long-legs, living in the soil and feeding upon the roots of grasses. In this way they spend the winter, reaching maturity in May, when they pass into the pupa-stage, the fully-formed insect appearing in June. In India these insects are known as elephant-flies, for even the thick hide of an elephant affords no protection against their sharp needle-like jaws. Judging from the account of a resident, horse-flies are a terrible plague in Florida. "Cows, horses, and mules have a wretched time in the summer, when they are eaten alive, and come home with the blood running down them. When driving, we used to spend all our time killing these soft, fat-bodied insects, which die at the least touch—in fact, the commonest kind never seem in any case to live more than twenty-four hours, and those which come into the houses are always dead the next morning. Their sting is really painful. I remember one day, when walking through the flat woods, suddenly feeling something like a pin running into my arm, and, on looking down, found it to be an extra big horse-fly. The arm was most tender for days after, feeling as though badly bruised, and was so much swollen as to make it quite a difficult matter drawing any sleeve over it. The 'coachman-fly' [doubtless one of the family *Asilidæ*] is said to feed on the horse-flies; and will sit through a whole drive on the collar, or some other part of the harness, or even on the steed itself, in order to pounce on the insects as they settle. The curious thing is that the horses seem to know the difference, for directly a horse-fly comes, even if it does not sting, they become restless, tossing their heads, and lashing with their tails, but the 'coachman' may rest on any part of them for any length of time, and never be interfered with, or driven off."



GREAT HORSE-FLY, WITH SIDE VIEW OF HEAD (nat. size).

Robber-Flies, etc.

The flies of the family *Asilidæ* are generally of a somewhat slender build, the body being long and parallel-sided, while the legs and wings are long and strong. All are provided with a short, powerful, piercing

proboscis, and prey upon insects of various kinds, often seizing and carrying off butterflies, much larger than themselves. The general form of the members of this family is shown in Fig. 1 of the annexed illustration, representing *Dioctria oelandica*, a species from the island of Oeland, off the coast of Sweden, with a shining black body, and wings of the same colour. Many species of the genus *Asilus* are found in Britain, but the largest and handsomest of all is the hornet robber-fly (*A. crabroniformis*), measuring upwards of an inch in length, and of a yellowish colour variegated with black, there being four stripes of the latter colour upon the thorax, and a broad transverse band across the base of the abdomen. Some of the tropical members of the family are far larger, those belonging to the genus *Mydas*, from South America, being scarcely surpassed in dimensions by any member of the order. The fly represented in 2 of the illustration is the tesselated empis (*Empis tessellata*), belonging to the family *Empidæ*, the species of which are predaceous like the *Asilidæ*, and resemble them in form, but differ in certain structural details which need not be dwelt upon. The tesselated empis — the largest member of the group found in Britain—is ashy grey in colour, and has its abdomen ornamented with a chess-board pattern. As Dallas expressed it, "when paired, the females of this and of many other of the larger species of the family are always found to be busily engaged in sucking out the juices of some other insect. It seems probable that the male seizes the opportunity of his intended partner being thus occupied to make his advances; if her mouth were free he would in all likelihood himself fall a sacrifice to her voracity."



ROBBER-FLIES.
1, *Dioctria oelandica*; 2, *Empis tessellata* (nat. size).

Bee-Flies.

The families of short-horned, straight-seamed flies hitherto considered resemble each other in the fact that the larvæ live in the earth, and feed upon the roots of grass or other vegetable matter, while the adults prey upon other animals, whose blood they suck. But in the bee-flies (*Bombyliidæ*)—so called from the likeness in hairiness and shape they present to humble-bees—the larvæ, so far as known, live parasitically on other insects, attacking grasshoppers, caterpillars, etc., while the adults suck the juices of flowers. The genus *Bombylius* is represented in England by a small number of species, although in the tropics there are large numbers of forms. In all the thick, fat body is covered with long yellow hairs. The wings are powerful; and the head is furnished with a long proboscis, which is thrust into blossoms while the insect (No. 8 on p. 65) stays poised in mid-air, like a hawk-moth when similarly occupied. The black-and-white bee-fly (*Anthrax semiatra*) is mostly of a black tint, and clothed with hair of the same colour; but the hairs on the front part of the thorax and abdomen take a yellowish tinge, the wings, as shown in the illustration, being black in the basal half but clear elsewhere. These insects may be seen on the wing in dry, sunny spots, stopping from time to time to suck a flower, or rest upon a stone, and seeking

for the cells of solitary bees wherein to deposit their eggs. The left-hand figure shows the cocoon of one of these bees, with the pupa-case, from which the fly on the right has just emerged, protruding from it. For the last family of this section (*Stratiomyidæ*) the common *Stratiomys chamæleon* may be taken as the type. This is a rather large insect, with a short broad abdomen, variegated at the sides with pale spots; the sides of the face and the posterior part of the upper surface of the thorax being also yellow. The antennæ are longish, and the hinder part of the thorax is armed with a pair of spines. The females, which may be seen on the wing in the neighbourhood of marshes, ponds, and ditches, lay their eggs on the leaves of water-plants, and the larvæ spend their time wriggling about in a helpless way. In these larvæ the body consists of twelve segments, is somewhat depressed, pointed at each end—though more so towards the tail than the head—and covered with a tough blackish brown skin. The head is small and pointed, and the retractile tail-segments are furnished at the tip with a breathing-orifice surrounded by a circlet of barbed hairs. By means of these the larva is enabled to suspend itself from the surface of the water, hanging vertically downwards with the orifice just above the water's level, and is also able by the folding in of the hairs to take a bubble of air below the surface when it sinks to the bottom. The larvæ feed on such particles of matter as they find in the water; and when ready to pass into the pupal stage creep to the land, and take refuge beneath a stone, or in some other place of safety. The development of the pupa and perfect insect takes place only in the front part of the larval skin. A curious choice of habitat for her young on the part of some flies belonging to this family has been recorded from Wyoming. These larvæ were found in a cup-shaped depression at the top of a cone about twenty inches high situated a few feet from a large sulphur mound, under which the boiling water could be heard. Through small apertures in the bottom the hot water rose and filled the cup. It was in this that the larvæ were found; and it is estimated that the temperature of the water was only twenty or thirty degrees below boiling point.



BLACK AND WHITE BEE-FLY, WITH PUPA-SKIN PROTRUDING FROM COCOON OF BEE.



FEMALE OF *Stratiomys chamæleon.*

CIRCULAR-SEAMED FLIES,—Suborder **Cyclorrhapha.**

This suborder, which is characterised by the circumstance that the pupa escapes from the larval skin through a circular aperture formed by the pushing off of the head-end, contains the majority of ordinary flies. It is divisible into two sections, the first of which includes those that present the normal method of development, the young being hatched from eggs laid by the mother, although very rarely the eggs hatch immediately before being laid. The second embraces those in which

the young are retained within the parent's body, and nourished at its expense until the pupa stage is reached. The flies of the last category are for this reason generally called Pupipara.

Hover-Flies. The family *Syrphidæ* includes a number of species which, although differing considerably in external form, may be distinguished from other members of the suborder by the presence of the so-called spurious vein in the wing—a vein lying between the third and fourth longitudinal veins, and crossing the short transverse vein (marked in the figure on p. 48) which unites them. They also bear considerable superficial resemblance, both in colour and shape, to various bees and wasps. The best known types are the hover-flies (*Syrphus*), drone-flies (*Eristalis*), and humble-bee flies (*Volucella*). The hover-flies of the genus *Syrphus*, which with their black and yellow bands mimic wasps, are so named on account of their habit of hovering in flower-gardens in summer, darting from blossom to blossom, and often sustaining themselves poised in mid-air, after the manner of a hawk. The females lay their eggs singly on leaves and stems infested with plant-lice; and the larvæ devour numbers of these pests, seizing them in a most voracious manner, sucking them dry, and rejecting the empty skins.



HOVER-FLY (*Syrphus seleniticus*).
1, Fly; 2, Fly hovering; 3, Larvæ devouring plant-lice on leaf; 4, Larva; 5, 6, Different views of pupa. (4, 5, 6, enlarged; the rest nat. size.)

Drone-Flies. Like the hover-flies, drone-flies (*Eristalis*) frequent flower-gardens, where they may be seen in numbers on various blossoms. As their name indicates, these flies resemble honey-bees, the likeness being so close that it is difficult to persuade an uninitiated person that they may be handled with impunity. The resemblance, which is enhanced by the ceaseless twitching of the abdomen, appears indeed to be more deeply seated than might at first be supposed, for spiders, which recognise their prey by touch and not by sight, treat the drone-flies with caution. Thus a blue-bottle fly placed in a web of the field-spider was immediately and without hesitation seized and devoured, although a humble-bee was avoided by the spider, which—evidently fearing to come to close quarters—let out a thread, and rushing round and round its victim at a distance, succeeded in winding it up, and then approaching, inflicted a bite which soon put an end to the insect's struggles. When a drone-fly was thrown into the web, the spider darted at it as before, but as soon as it touched the fly with its fore-legs, recoiled, as if in alarm, then returning to the attack dealt with the harmless victim just as it had previously acted with the humble-bee. The larvæ of the drone-flies live mainly in ditches and feed upon decaying organic matter, and are

commonly known as rat-tailed maggots, on account of the long tail-like appendages at the hinder end of the body. With this flexible and telescopic tail, traversed by tracheal tubes opening at its tip, the maggot is able to breathe while below the water, by keeping the tip of its tail above the surface, where it is supported by the rosette of hairs round the extremity. The eggs of drone-flies are also laid in dead carcases and other refuse, and it is now believed that the legend of the ox-born bees of the ancients is traceable to this habit of the fly, in conjunction with its striking resemblance to the honey-bee. The belief that honey-bees are produced by spontaneous generation from carcases of dead animals has prevailed for more than two thousand years, but according to Osten Sacken, "the original cause of this delusion lies in the fact that a drone-fly (*Eristalis tenax*) lays its eggs upon the carcases of animals, that its larvæ develop within the putrescent mass, and finally change into a swarm of flies, which in their shape, hairy clothing, and colour look exactly like bees, although they belong to a totally different order of insects." Scarcely less interesting than the drone-flies are the species of *Volucella*. These large flies (p. 65, No. 9) mimic humble-bees in colour and form; and it was long supposed that the females were thus enabled with impunity to enter the nests of humble-bees and lay their eggs amongst those of the proper owners. But although it is true that the eggs of the *Volucella* are laid and the larvæ reared inside the nests of various Hymenoptera, it has been ascertained that the species which resemble humble-bees visit for the same purpose the nests of wasps, to which the flies bear no particular resemblance. And it is hardly credible that the wasps give access to the flies under the delusion that they are members of the community, as was conceivable in the case of the bees. We are compelled therefore to conclude that the flies are allowed by the bees and wasps to come and go without interference for some reason apart from the resemblance that exists between the two sets of insects. It is, of course, possible that the similarity offered by the flies to bees and wasps is more deeply seated than was supposed, and affects such senses as touch or smell, or some other unknown sense, but there seems no evidence to justify this supposition; and if the maggots of the flies feed on the larvæ of the bees or wasps, we are not yet in a position to offer an explanation of the phenomenon. If they play the part of scavengers, clearing the hive of waste matter, the reason for the admittance of the flies becomes clear.

Closely resembling many of the *Syrphidæ* in their banded coloration, which imparts to them a wasp-like aspect, the members of the family *Conopidæ* may be recognised by the absence of the spurious vein in the wings, and also by their broad heads, of which the fore-part is produced into a conspicuous prominence bearing the long antennæ. Like the horse-flies, the *Conopidæ* in the adult stage frequent flowers, but they lay their eggs in the bodies of various Hymenoptera, like bees and wasps, and also in crickets and other Orthoptera. Here the eggs hatch and the larvæ feed upon the living tissues of their prey, and here they undergo their metamorphosis, although they do not invariably quit the place of their development upon the death of the victimised host. Taschenberg, for example, found the pupa of *Conops vittatus* emerging from the abdomen of a humble-bee which had been for six months in his collection. The *Conopidæ* are widely distributed, and especially abundant in the tropics.

Bates gives an account of the habits of a species which he noticed hovering over the armies of foraging ants. These ants, he says, "are accompanied by small swarms of a kind of two-winged fly, the females of which have a very long ovipositor, and which belongs to the genus *Stylogaster*. These swarms hover with rapidly vibrating wings, at a height of a foot or less from the soil over which the ants are moving, and occasionally one of the flies darts with great quickness towards the ground. I found that they were not occupied in transfixing ants . . . but most probably in depositing their eggs in the soft bodies of insects which the ants were driving away from their hiding-places. These eggs would hatch after the ants had placed their booty in their hive as food for their young."

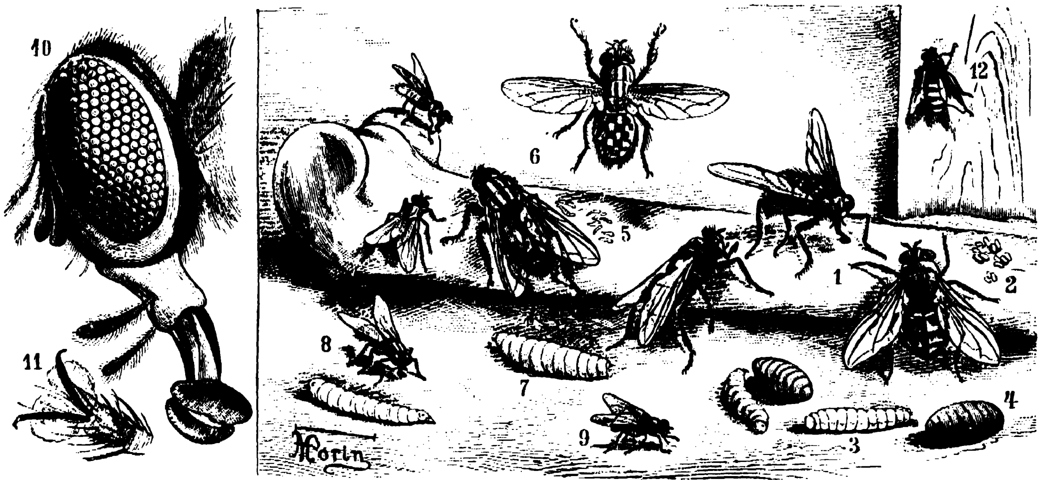
Typical Flies. The family *Muscidæ* embraces a large and varied assortment of species, of which house-flies and blow-flies are well-known examples. The characteristic structure of the wings may be seen by referring to the figure on p. 48. The proboscis is adapted for sucking, and usually ends with two fleshy lobes. The flagellum of the antennæ is generally plumed with hairs on both sides, though sometimes, as in the tsetse, the hairs are restricted to one side, while in the spiny-flies it may be naked. The relative size of the three basal segments of the antennæ varies in different genera, but usually, as in the blow-flies, the house-flies, and the tsetse, the third segment is at least three times the length of the second (see *b* in figure on p. 69, and 10 in that on p. 65). It may also be mentioned that the upper surface of the thorax is marked with a transverse suture, and that the feet are furnished with a pair of adhesive pads (11 in the figure on p. 65). The family is divided into several subfamilies, and these may be grouped in two sections, based upon the presence or absence behind the wings of a membranous scale which, when present, covers the *halteres* or balancers. The subfamilies that possess this scale are termed the calypterate *Muscidæ*; while those that are without it are in contrast called the acalypterate *Muscidæ*. Taking the calypterate *Muscidæ*, we begin with the subfamily *Muscinæ*, of which the house-fly (*Musca domestica*) is the typical representative. This species may be found during summer in numbers in every house, crawling up the window-panes, flying in companies about the middle of the room, or creeping about the table in search of food. It is the unwelcome companion of man in every country, following him in his travels, taking up its residence with him wherever he may choose to settle, and resisting equally well the cold of northern latitudes and the heat of tropical climes. For the most part, the eggs are laid and the larvæ undergo their development in excrement; but the choice of the female does not seem to be always restricted to matter of this sort, since she sometimes selects meal, bread, or fruit, for the purpose. These flies are liable to the attacks of a parasitic fungus (*Empusa muscæ*) which causes their death, and in autumn it is not uncommon to find their bodies killed by this means, with the abdomen much distended, and showing the soft membrane between the segments. The common blue-bottle or blow-fly (*Calliphora erythrocephala*) is too well known to need description. One of the most noteworthy features connected with this fly is the extraordinary keenness of the sense—perhaps smell, which enables it to discover the whereabouts of carcases, however small, or of particles of meat. In these it hastens to lay its eggs; and in a longer or shorter time, according to temperature, the eggs hatch, and the larvæ,



INSECT LIFE IN SUMMER.

, Common Wasp; 2, 3, Honey-bees; 4, Hairy-legged Bee (*Dasypoda*); 5, Wasp (*Pompilus*); 6, Stone Humble-bee; 7, Common Humble-bee; 8, Bee-fly (*Bombylius*); 9, Humble-bee Fly (*Volucella*); 10, Spiny Fly (*Tachina*); 11, Noctuid Moth (*Anarta*); 12, 13, Field Tiger-Beetle, crawling and flying; 14, Wood Tiger-Beetle; 15, Rose Beetle (*Cetonia*); 16, Dung-Beetle (*Typhœus*); 17, Field-Cricket; 18, Grasshopper (*Stenobothrus*).

feeding upon the meat, rapidly grow until they reach maturity and pass into the pupa stage. Many persons believe that blue-bottles are full-grown examples of the house-fly, and when informed that such is not the case, and that these insects after reaching the winged stage are incapable of growth, point out that blue-bottles vary greatly in size, and ask what may be the explanation of the difference. The answer is, that the size of the blue-bottle in its final stage depends upon the size of the maggot before pupating, and the size of the maggot upon the amount of nourishment it is able to obtain before its supply of food was exhausted. In any given case, when the supply is limited, the maggots that are the first to hatch will get more food than those that appear later, and in consequence, when the whole of it is exhausted, will have attained a greater length and fatness than the others, and thus become converted into larger flies. Or,



GROUP OF FLIES AND THEIR GRUBS.

1, Blow-fly ; 2, Eggs ; 3, Larvæ ; 4, Pupa ; 5, Newly-born larva of grey flesh-fly ; 6, Grey flesh-fly : 7, Adult-larva of the same ; 8, House-fly and larva ; 9, Sharp-mouthed fly ; 10, Head of house-fly ; 11, Foot of grey flesh-fly ; 12, Carcase of house-fly killed by fungus growth. (10, 11, enlarged ; the other nat. size.)

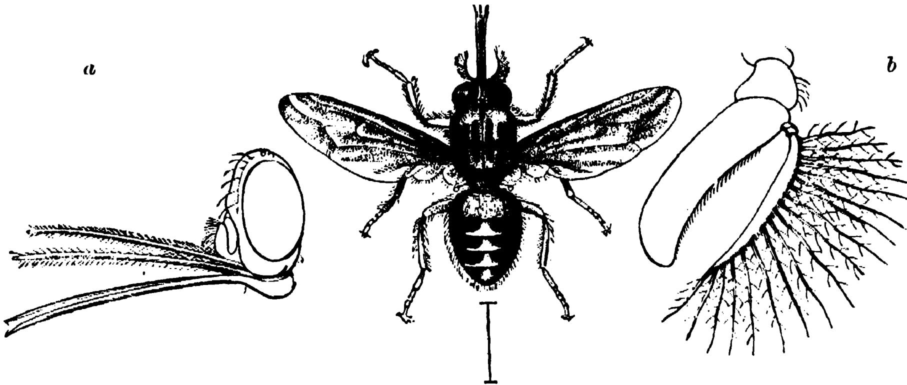
again, if three or four hundred eggs be laid in a dead mouse and the same number in a dead rabbit, it is clear that in the former case the supply of food will be smaller for each larva, and will sooner come to an end than in the latter.

The grey flesh-fly (*Sarcophaga carnaria*) is a handsome species, measuring in the female half an inch in length. Seldom entering houses, it is not uncommon in the open country, where it may be seen basking in the hot sun upon stones or walls. Its prevailing colour is pale slate-grey, variegated on the thorax with black bands, and the abdomen with square black spots, set corner to corner like the squares of a chess-board. A noteworthy fact connected with this species is that the eggs hatch within the parent before being laid, so that the young are born alive; they feed upon decaying animal and vegetable matter. The blow-flies belonging to the genera *Calliphora* and *Lucilia*, respectively known as the blue-bottle and green-bottle flies, as a general rule deposit their eggs upon dead animal matter. This, however, is by no means always the case, there being many instances on record of the laying and hatching of the eggs upon living

animals. Thus it is by no means uncommon for sheep to be attacked in this way by a green-bottle fly (*L. silvarum*). On this subject, Mr. Reeks writes that "these flies deposit their eggs in the wool of sheep, generally about the root of the tail or behind the shoulders, anywhere, in fact, where the wool is most greasy. The larvæ of these flies are most troublesome to shepherds in the latter part of May and June, until the sheep are sheared, and much later in the summer with lambs, when they should be dipped in a preparation of arsenic and soft soap." Toads and frogs also seem to be frequently selected as objects of attack on the part of these flies. In one case the eggs of a green-bottle fly were laid on a toad's back, and the larvæ upon hatching migrated into its eyes. In other cases the laying of the eggs and migration of the larvæ have not been actually observed, but toads have been found with their nostrils infested with maggots; and it is possible that the latter may have effected an entry from the outside, as described above. Mr. Guthrie, who noticed the occurrence of the larvæ of a blue-bottle (*Calliphora*) in the nostrils of toads, writes that "it is probable that the number of toads is largely kept under by those means. In 1872 toads were remarkably plentiful in the neighbourhood of Tenby, South Wales, and I noticed that the disease was very prevalent amongst them. In the following year scarcely any could be found, and I saw none diseased." Cases are also on record of the death of lizards from maggots of blow-flies, which testify to the extraordinary vitality of the latter. In one instance a gecko fed on blue-bottles was found to have the whole abdominal region greatly distended. It soon afterwards died, and on dissection its intestines, lungs, and liver were found to be almost entirely destroyed by maggots, whose presence was naturally attributed to eggs from gravid female blue-bottles, which had been swallowed as food. In another case, some lizards fed on the living maggots of the blue-bottle died in consequence of the attacks on their internal organs by their intended food. Far more important are the cases of infection of human beings; the resulting sickness, which often entails great suffering, and may end in death, being known as *myiasis*.

The sharp-mouthed fly (*Stomoxys calcitrans*), represented in 9 of the figure on p. 65, closely resembles the house-fly in size, shape, and colouring, but may be recognised by its sharp, horizontally projecting proboscis, and also by the flagellum of the antennæ being hairy upon one side only. It is less often seen in houses than the house-fly, although occasionally paying them a visit, especially if there be stables in the vicinity. By means of its proboscis this fly pierces the skin of cattle and horses, or even of man, and gorges itself on the blood. Its eggs are laid in the excrement of the cattle on which it feeds. Resembling *Stomoxys* in habits and in the structure of its antennæ and mouth-parts, the tsetse fly (*Glossina morsitans*) of Equatorial Africa, although barely equalling a blow-fly in size, is one of the greatest pests to domestic cattle, as the following accounts amply testify. As shown in the annexed illustration, the proboscis of this fly is long and prominent, and the antennæ (*b*) are peculiar in that the third segment is very long and produced almost as far as the apex of the flagellum, which is furnished with barbed hairs along its outer surface only. Writing of the tsetse, Livingstone says that "we had come through another tsetse district by night, and at once passed our cattle over to the northern bank, which, though only fifty yards

distant, was entirely free from the pests. This was the more singular that we often saw natives carrying over raw meat with many tsetse upon it. This insect is not much larger than the common house-fly, and is nearly of the same brown colour as the honey-bee. The after part of the body has three or four yellow bars across it. It is remarkably alert, and evades dexterously all attempts to capture it with the hand at common temperatures. In the cool of the mornings and evenings it is less agile. Its peculiar buzz when once heard can never be forgotten by the travellers whose means of locomotion are domestic animals, for its bite is death to the ox, horse, and dog. In this journey, though we watched the animals carefully, and believe that not a score of flies were ever upon them, they destroyed forty-three fine oxen. A most remarkable feature is the perfect harmlessness of the bite to man and wild animals, and even calves so long as they continue to suck the cows, though it is no protection to the dog to feed him on milk. The poison does not seem to be injected by a sting, or by ova placed beneath the



TSETSE FLY (enlarged).
a, Side view of head ; *b*, Antenna.

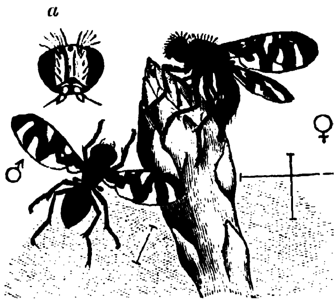
skin, for, when the insect is allowed to feed freely on the hand, it inserts the middle prong of the three portions into which the proboscis divides somewhat deeply into the true skin. It then draws the prong out a little way, and it assumes a crimson colour as the mandibles come into brisk operation. The previously shrunken belly swells out, and, if left undisturbed, the fly quietly departs when it is full. A slight itching irritation follows the bite. In the ox the immediate effects are no greater than in man; but a few days afterwards the eyes and nose begin to run, the coat stares, a swelling appears under the jaw, and sometimes at the navel; and though the poor creature continues to graze, emaciation commences, accompanied with a peculiar flaccidity of the muscles. This proceeds unchecked until, perhaps months afterwards, purging comes on, and the victim dies in a state of extreme exhaustion. The animals which are in good condition often perish soon after the bite is inflicted with staggering and blindness, as if the brain were affected. Sudden changes of temperature produced by falls of rain seem to hasten the progress of the complaint, but, in general, the wasting goes on for months. When the carcase is opened, the cellular tissue beneath the skin is found injected with air, as if a quantity of soap-bubbles were scattered over it. The blood is small in quantity, and scarcely stains the hands in dissection. The fat is of a

greenish yellow colour, and of an oily consistence. All the muscles are flabby, and the heart is often so soft that the fingers may be made to meet through it. The lungs and liver partake of the disease. The stomach and bowels are pale and empty, and the gall-bladder is distended with bile. These symptoms seem to indicate poison in the blood, the germ of which enters when the proboscis is inserted. The mule, ass, and goat enjoy the same immunity from the tsetse as man and the game. Many large tribes on the Zambesi can keep no domestic animals except the goat, in consequence of the scourge existing in their country. Our children were frequently bitten, yet suffered no harm; and we saw around us numbers of zebras, buffaloes, pigs, palas, and other antelopes feeding quietly in the very habitat of the fly. There is not so much difference in the natures of the horse and zebra, the buffalo and ox, the sheep and the antelope, as to afford any satisfactory explanation of the phenomenon." With the gradual spread of civilisation, it might be supposed that the ravages of this pest would become lessened, but this does not appear by any means to be the case. Writing in 1881, Mr. Selous remarks that "nowhere does this virulent insect exist in such numbers as to the westward of the Victoria Falls, along the southern bank of the Zambesi and Chobi. It is usually found in great numbers near the rivers, becoming scarcer and scarcer as one advances inland, till at a distance of a few miles it disappears, except in some particular patches of forest. Along the water's edge they are an incredible pest, attacking one in a perfect swarm, from daylight till sunset; and without a buffalo or giraffe tail to swish him off, life would be unendurable. . . . About one in every ten bites (that perhaps touches a nerve) closely resembles the sting of a wasp or bee, as it will cause one, when seated to spring up as if pricked with a needle. . . . I think that this plague of the tsetse flies along the Chobi and Zambesi is due to the enormous numbers of buffaloes that frequent their banks, as they always seem very partial to these animals. The bite of this remarkable insect, as is well known, though fatal to all kinds of domestic animals, is innocuous to every species of game and to man. A general belief exists that among domestic animals, the donkey, dog, and goat are exceptions to this rule; but this is a mistake, for I have seen all three die from the effect of its bites." The genus to which the common tsetse belongs is represented in South Africa by several species, all of which seem to be similar in habits. It ranges from Somaliland in the east and the Congo in the west, southwards as far as the Limpopo. Fortunately it is not universally distributed throughout the country, being somewhat local in its distribution, and inhabiting definite tracts of land, corresponding with the beds of rivers, from which it does not appear to spread to any great distance.

Another group of flies constitutes the subfamily *Tachininæ*, of which the best known examples are the spiny-flies (*Tachina*), so called on account of the thickness of the bristles with which their bodies are clothed. Of stout and robust build, these flies present a great resemblance to blow-flies and their allies, but have the bristles of the antennæ naked, or feathery only at the base, and the scales covering the balancers of larger size. The larvæ, like those of the *Conopidæ*, live parasitically upon other insects, such as beetles, grasshoppers, and caterpillars. The great spiny-fly (*Echinomyia grossa*), rather a local species, is the largest

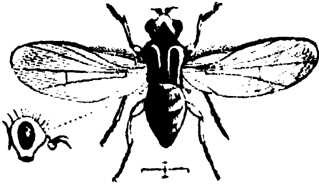
representative of the family found in Britain. It is about two-thirds of an inch long, with a short, broad, oval abdomen; the shining black of its body being relieved by the reddish yellow colour of the head and the base of the wings. The allied species (*E. ferox*) represented in the illustration is brownish, with the abdomen tinted with red at the sides. Belonging to the same subfamily is the Australian fly *Rutilia*, remarkable among the order for being ornamented with bright metallic green spots. By reason of their external form and general colouring the flies of the subfamily *Anthomyinæ* appear to the casual observer to be nothing but ordinary house-flies; but they may be distinguished from the latter by the absence of the apical transverse vein on the wing (marked *d* on the figure of the fly's wing on p. 48). The scales, moreover, which cover the *halteres* are very small, and lead up to the condition found in those flies in which they are absent. The larvæ, which differ from those of the house and blow-flies in being covered with spines, live on plants of various kinds, those that have attracted the most attention being the species that attack cultivated vegetables, such as onions, cabbages, lettuces, radishes, and the like. Those members of the family having no scales covering the balancers and assigned to the subfamily *Trypetinæ* are generally of small size, many being very obnoxious on account of the damage inflicted by their larvæ on various marketable vegetables. Of the numerous species it is only possible to notice a few. The first is the painted-winged asparagus-fly (*Platyparea pœciloptera*), which, as its name indicates, has variegated wings, and attacks asparagus. The male is smaller than the female, as shown by the length of the lines in the figure, and the latter sex may be recognised by the possession of a long ovipositor, by means of which she deposits her eggs between the scales of the head of the asparagus. The laying takes place about the beginning of May, and in two or three weeks, according to the season, the eggs hatch, and the larvæ burrow into the stalk of the plant. In a fortnight or so the latter reach maturity, and, after passing through the pupa stage, develop into flies towards the end of June. Many more or less nearly allied species are found in England and other countries, but it will suffice to indicate a few of the more important. Of these the cherry-fly (*Spilographia cerasi*) and the olive-fly (*Dacus oleæ*) devour in their larval stages the fruits after which they are named; while the various species of the genus *Ceratitis* similarly attack the orange. Recently *C. capitata* was very destructive to the mandarin oranges in Malta, and seems to have been first introduced into the island about twenty years ago. This fly is lively and hardy, as shown by the fact that a specimen kept under a glass shade without food maintained its activity for twelve days. When egg-laying, the female chooses the side of the fruit exposed to the sun, where it perforates the rind so that the larvæ upon hatching start at once to devour the nutritious food. The


SPINY FLY (*Echinomyia ferox*), WITH LARVA AND PUPA (nat. size).



ASPARAGUS FLY, ♂ male; ♀, female. (*a*) Front view of head.

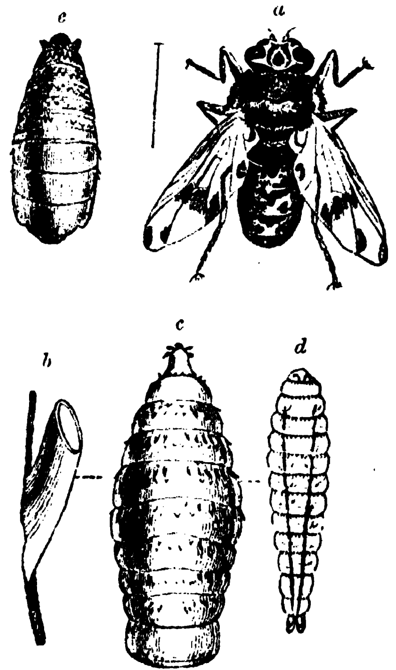
infected fruit drops to the ground, and the larvæ when mature pass out to become pupæ beneath the earth. Besides oranges and other acid fruits, peaches and melons are attacked by this fly. The annexed figure represents another of these injurious little insects (*Chlorops tæniopus*), a shining yellow fly variegated with black bands. This species and its allies, which are most destructive in the larval stage to cereals and grass, much resemble in the cycle of their development the above-mentioned Hessian fly. Allied to the preceding in structure and habits are the members of the sub-family *Ortalinæ*, containing the genus *Ortalis* and others. A curious representative from the Malay Archipelago, known as the staghorn-fly (*Elaphomyia*), takes its name from the development of the sides of the head into large branching horns. This, however, is only a sexual character, and confined to the male. Finally, the small black fly (*Piophila casei*), known in the grub-stage as the cheese-hopper, belongs to that group of *Muscidæ* in which there are no scales to cover the balancers.



Chlorops tæniopus, with figure showing side view of head (much enlarged).

GAD-FLIES AND BOT-FLIES,—Family *ŒSTRIDÆ*.

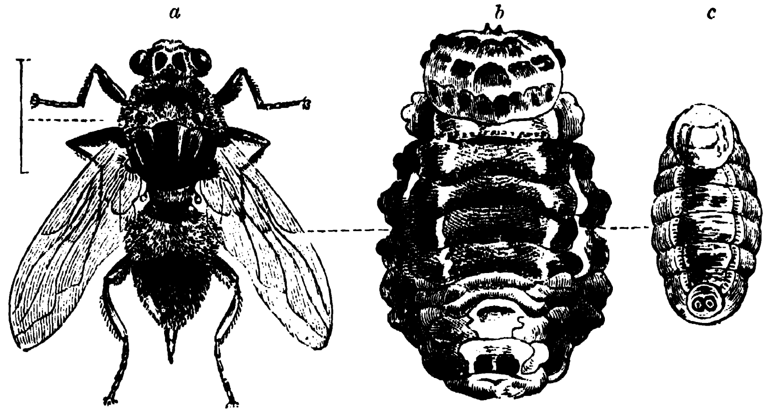
The flies of this family are mostly of large size, and many present superficial resemblance to various kinds of bees. In structural characters they are nearly allied to house-flies, but the head is larger and broader and the mouth-parts are reduced. In the larval stage gad-flies infest, either as internal or external parasites, various mammals, but since those that attack domestic cattle have been more thoroughly studied than the others, attention will mainly be directed to three of the best known forms, namely, those that infest respectively horses, oxen, and sheep. The horse bot-fly (*Gastrophilus equi*), which resembles the honey-bee in size, colour, and form, lays its eggs on the skin of horses, asses, and mules, which seem to have an instinctive dread of the insect. It has been noticed, moreover, that the gad-fly instinctively selects for the purpose a spot that is well within reach of the quadruped's mouth. The reason for this, although not at first very obvious, becomes clear when it is understood that the larval fly can only obtain its proper nourishment in the alimentary canal of its host. As soon as the maggot emerges from the egg it starts to irritate the horse's skin. Thereupon the horse, to remove the irritation, licks the infested spot and swallows the maggots, which then attach themselves by means of their hook-like mandibles to the inner wall of the stomach or



DEVELOPMENT OF HORSE BOT-FLY.

Adult fly; *b*, Egg attached to a hair; *c*, Mature larva; *d*, Newly-hatched larva; *e*, Pupa. (All enlarged.)

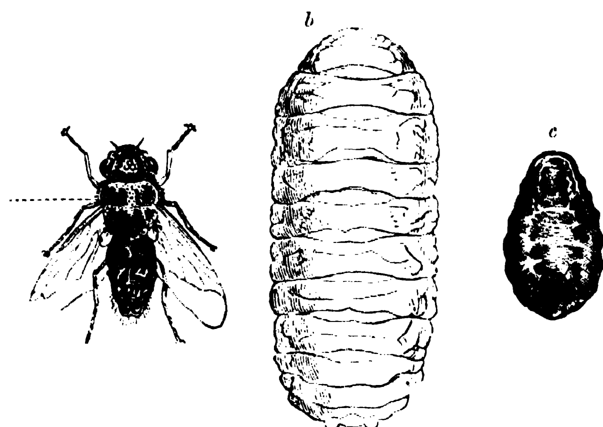
œsophagus, making little excavations, and nourishing themselves by sucking up the secreted mucus. Here in perfect security they live and grow for about a year; after which, when nearly full grown, they enter the intestine and pass out of the body with the excrement. Falling to the ground, the maggots bury themselves in the soil and enter upon the pupal stage. In favourable weather the perfect insect is produced from the pupa in about six weeks. The ox-bot, or ox-warble (*Hypoderma bovis*) deposits its eggs in the hair of the skin of cattle, and the maggots after hatching burrow through the skin and take up their lodging in the tissues beneath, where in course of development they give rise to the large tumours known as warbles, each of which opens to the exterior by means of a small aperture. In these tumours the maggots remain for ten or eleven months until practically full grown, when, quitting their host, they fall to the ground, bury themselves, and in the course of a month or six weeks emerge from the pupa stage as fully developed flies. The species most commonly met with in England is not *H. bovis* but *H. lineatum*. It can be easily understood from the fact that since no fewer than four hundred maggots, each growing to an inch in length, have been known to infest a single beast, the loss occasioned by the attacks of this fly is considerable. It has been estimated, indeed by Stratton, that in the United Kingdom alone a loss of something like £8,000,000 per annum is sustained. The mischief begins in the summer, when the cattle gallop about in terror in their vain efforts to escape the flies seeking to deposit their eggs upon them. This causes waste of milk and damage to health. Then there is the damage to the meat by the destruction of the tissue just under the hide, resulting in what butcher's call licked meat or jelly. And lastly, there is the evidence of tanners as to the damage to hides; one estimate given by a firm putting the loss on hides sold at two markets in Birmingham during seven weeks at £545; while a Nottingham authority reckons the loss in that town at £1500 to £2000 per annum. The sheep bot-fly (*Œstrus ovis*) lays its eggs in the nostrils of sheep, and the maggots after being hatched pass up the nasal passages and enter the chamber in the bones of the forehead, where they nourish themselves on the mucus to which the irritation of their presence gives rise. The presence of these parasites, which are seldom fewer than seven or eight at a time, is most injurious to the infested animal, and gives rise to a sickness of a very serious nature. At the end of about nine months the larvæ reach maturity, and making their way again into the nostrils are expelled by the sneezing of their



OX WARBLE-FLY AND ITS DEVELOPMENT.

a, Fly; *b*, Larva; *c*, Pupa—the latter from the lower side. (All enlarged.)

host, and reaching the ground bury themselves, and remain concealed until they emerge as perfect insects from the pupal stage. The three species above mentioned serve as types of the life-histories of the entire family, which contains in addition a large number of genera and species infesting various kinds of animals. Even man himself is not exempt from their attacks, and all kinds of domestic cattle and beasts of burden, such as reindeer, camels, and elephants, are liable to be infested with them. Two notices of the occurrence of larvæ in human beings were published by John Howship in 1833. In both cases the larvæ, named *Œstrus humanus*, were extracted from tumours, the sufferer in one case being a soldier in Surinam, and in the other a carpenter in Columbia. In addition to the mammals mentioned, others, such as hares, rabbits, mice, and voles, often suffer from these parasites. Their larvæ have also been met with in birds and frogs. Schneider, for instance, states that two larvæ much resembling those of *Hypoderma* were obtained from under the skin of the head of a young sparrow, where they had produced two large hard tumours, and Krefft has given descriptions of specimens belonging to the genus *Batrachomyia* that were found living parasitically upon Australian frogs. The larvæ were situated between the skin and the flesh behind the drum of the ear, and could be squeezed out through apertures in the skin.

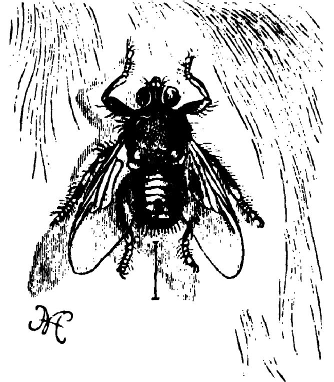


LIFE-HISTORY OF SHEEP BOT-FLY.
a, Adult fly ; *b*, Larva from upper side ; *c*, Pupa from under side (all enlarged).

FOREST-FLIES,—Family *HIPPOBOSCIDÆ*.

This family brings us to the second section (Pupipara) of the Cyclorrohapha, all the members of which are no less remarkable amongst flies for the strangeness of their appearance than for their method of development. They are all short and flat, with longish and powerful legs which enable them to run with great speed; some of them being entirely wingless, with the mouth-parts much reduced; but in the mode of their development they are absolutely unique in the entire order. In the first place only a single young one at a time is produced, and this, instead of being laid in the egg-stage, remains within the mother, nourished at her expense by means analogous to those which obtain in the higher mammals. When born, the young is either actually a pupa, or immediately assumes the pupa-state, being motionless, without segmentation, and entirely protected by a horny shell, which imparts to it the appearance of the seed of a vetch. The members of this section, which are mostly parasitic on birds or mammals, are referable to three families. Of these, the forest-flies are represented by several genera, all the members of which are parasitic upon mammals or birds, and are frequently spoken of as

ticks. The species known from its abundance in the New Forest as the forest-fly (*Hippobosca equina*) has the wings well developed. It infests horses and oxen, usually attaching itself to those parts of the body where the covering of hair is scanty. A second kind, known as *Ornithomyia avicularia*, occurring, as its name indicates, on birds of almost all kinds, also possesses a pair of fully developed wings; but in another species, *Stenopteryx hirundinis*, which is found on swallows and about their nests, the wings are narrow and sickle-like and scarcely fitted for flight. A fourth species, the so-called deer-tick (*Lipoptena cervi*), is provided with wings upon issuing from the pupa-case; but after flying about for a time the insects settle upon deer, and drop their wings by fracturing them at the base. The last member of the family to be mentioned, the so-called sheep-tick—which must not be confounded with the mite of that name—is entirely wingless from its birth. We thus get in this family a series of forms starting with the fully-winged forest-fly and leading through the swallow-tick with its wings reduced in size, and the deer-tick which can cast its wings, to the sheep-tick which has entirely lost these organs. The second family of the group, *Nycteribiidæ*, contains the single genus *Nycterbia*, the species of which live parasitically upon bats. All are wingless and have lost their compound eyes, but possess the balancers. The legs are long, powerful, and furnished with strong hooked claws, by means of which they cling to the hosts they infest. The bee-louse (*Braula cæca*; G. on p. 38), the type of the family *Braulidæ*, is a minute, blind, and wingless insect infesting honey-bees; being found upon the workers, as well as upon the drones and queen, but seeming to have a preference for the two latter as hosts.

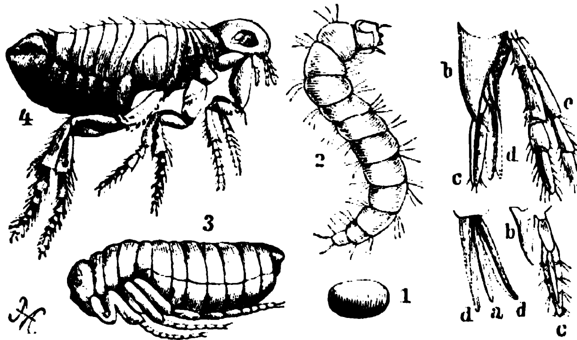


COMMON FOREST-FLY (enlarged).

THE FLEAS,—Family *PULICIDÆ*, etc.

The fleas, which by some are regarded as an order (Aphaniptera), may be considered to be aberrant flies; their mouth-organs, which are adapted for piercing and sucking, being modified upon the same principles as obtain in the flies. They further resemble that group in undergoing a complete metamorphosis, but differ from the majority of flies in being destitute of wings. The group is divisible into two families. In the true fleas or *Pulicidæ* the body of the adult is strongly flattened from side to side, and thus, in conjunction with the smooth, hard, and nearly naked integument, enables the insect to swiftly traverse the hairy coating of its host. Some of the segments, however, are usually armed with strong backwardly-projecting spines. There are no compound eyes, but each side of the head is furnished with a simple eye; the legs being long, strong, and fitted for leaping. The eggs are laid about the floors of houses, kennels, etc.; and the larvæ, which are slender, worm-like creatures, devoid of legs, but furnished with a biting mouth, live on particles of decaying organic matter found in the dust of the places they infest. When adult, the larva, or maggot, is said to spin a cocoon within which the pupa state is passed.

In addition to mankind, fleas (*Pulex*) live parasitically upon other animals such as dogs, cats, badgers, pigeons, fowls, moles, hedgehogs, squirrels, etc. They are, moreover, even more abundant in tropical than in temperate countries. Tennent, for instance, says that in Ceylon "they may be seen in myriads in the dust of the streets, or skipping in the sunbeams which fall on the clay floors of the cottages. The dogs to escape them select as their sleeping-places spots where a wood fire has been kindled; and here, prone on the white ashes, their stomachs close to the earth, and their hind-legs extended behind, they repose in comparative coolness, and bid defiance to their persecutors."



COMMON FLEA AND ITS STRUCTURE.

1, Egg; 2, Larvæ; 3, Pupa; 4, Perfect insect; *a*, Labrum; *b*, Labium; *c*, Labial palpi; *d*, Mandible; *e*, Maxillary palpi.

To the family *Sarcopsyllidæ* belongs the dreaded chigoe or jigger (*Sarcopsyllus penetrans*) of tropical countries. The adult female burrows beneath the skin of the foot, and shortly after effecting an entrance her body becomes swollen up with eggs, and grows to the size of a pea. At this stage she may be easily extracted, and as the young are not parasitic it is seldom that serious results ensue. According to Mr. W. H. Blandford, "the recorded distribution of the chigoe extends over Tropical America and the Antilles, from 30° N. to 30° S., and in late years it has been exported in ballast to Africa, and has established itself in Angola, Loango, and the Congo." It also occurs in British Central Africa, where quite recently it occasioned much suffering among the natives, and, by laming the native postmen, caused delay in the transmission of mails. As in the case of the *Pulicidæ*, the fleas of this family do not confine their attentions to mankind. There is, for example, a genus known as *Vermipsylla*, which occurs in Turkestan, and is said to be very injurious to cattle; and Mr. Blandford has recently recorded a species from Ningpo in China, found buried in the ears of sewer-rats. Speaking of the occurrence of the jigger in Florida, a correspondent writes that "the wooden houses are built on piles, and under them the sand is infested with jigger-fleas. All dogs are attacked by them, and fowls and puppies frequently killed: in fact, sitting hens must regularly have their combs covered with lard and brimstone, and insect powder dusted over their wings, to keep them alive. These jiggers are very tiny and black, and do not hop like Old World fleas, but, fixing themselves into the flesh, stick there, and are most difficult to remove. An English visitor who has once collected eggs in a Florida hen-house, on a hot June day, will for ever remember the result."

R. I. POCOCK.

CHAPTER III.

JOINTED ANIMALS,—*continued.*

INSECTS,—*continued.*

BUTTERFLIES AND MOTHS,—Order LEPIDOPTERA.



PINE HAWK-MOTH WITH LARVÆ AND PUPA.

THE beautiful insects comprehended in the order to which the name Lepidoptera or scale-wings has been given are familiar to the majority of readers without any lengthened introductory description. The butterflies, or Rhopalocera, and the moths, or Heterocera, though they form two distinct sections of the order, cannot be divided by any hard-and-fast lines. They may generally be distinguished from one another by the manner of the folding of the wings at rest, or more precisely by the different character of the antennæ. The wings of the moths, too, are locked together by a tiny hook on the inner margin of one wing fitting into an eye on the inner margin of the other. The butterflies never possess this curious structure. The Lepidoptera are easily distinguishable from other orders of insects by the four ample wings, with more or less regular veins or nervures, clothed with the minutest, exquisitely-chiseled scales, of many shapes, and great variety of external chasing. These scales are but modified forms of hairs, broadened out, flattened and fashioned to cover the delicate membrane of the wing with an overlapping armament of beauty. And it is to this wondrous sculptured dust, breaking up the

rays of sunlight as it plays upon the surface of their wings, that butterflies and moths owe their tender shades, brilliant colours, and metallic lustres. A few butterflies are clear-winged, with scarcely any scales, such as the *Ithomia* of Brazil, while the *Sesiidæ* represent the clear-wings amongst the moths. Some orders of insects, such as the Hymenoptera, have four membranous wings like the Lepidoptera, but these are transparent and not clothed with scales. Others, such as the beetles, have the upper pair horny and useless for purposes of flight, the second pair being membranous but not scaly. The mandibles, or jaws, found in most other four-winged insects except the Hemiptera or bugs, are replaced in the Lepidoptera by a long tubular proboscis or suctorial apparatus, used for exhausting the contents of honey-bearing flowers, or drawing in nutriment from less tasteful sources. In common with all other insects, the Lepidoptera have the body divided into three separate sections. The head, bearing the eyes, proboscis, and antennæ; the thorax, whence originate the legs below and the wings above; and lastly the abdomen, bearing along the sides the spiracles for breathing, and the generative organs at the apex. The abdomen is never attached by a narrow stalk or pedicle as in the Hymenoptera. So close may their general resemblance be to other insects, that, as is the case with the hornet clear-wing moth, none but a naturalist could distinguish it from the common hornet. A general resemblance of body-plan may coexist in individuals of two widely separate orders, together with a habit of life and temperament, and likewise essential characters, wholly distinct and different.

Development. The Lepidoptera also resemble the insects of most other orders in passing through several sharply defined phases before the last and perfect stage is attained. All first appear in the form of an egg laid by the mother on some food-plant or tree. On hatching, the eggs give rise to a free-walking, feeding, sleeping, and breathing larva or caterpillar; thence, after successive changes of the skin, this passes into the quiescent, trance-like state, called the pupa or chrysalis stage; from this it at last emerges, at a suitable season of the year, as the fully formed butterfly or moth. At the commencement of life the butterfly or moth is a thing of beauty even in the egg state. Butterflies' eggs, though falling into distinct groups of resemblance, on which even systems of classification have been based, are as various as they are beautiful. Globular, oval, flat, barrel-shaped, bottle-shaped, green, white, or brown, the egg is usually of a hue which renders it not easily visible on the leaf where it has been deposited. After a time the shell bursts, the tiny larva creeps forth, and commences feeding either on the egg-shell or on the food lying in abundance near at hand. The larvæ are long, cylindrical, creeping, worm-like objects, with short legs, and a more or less hairy or quite naked body. The greater number feed upon the leaves of trees, shrubs, plants, and grasses; while many are internal feeders, burrowing deep into the decaying hearts of various trees. Others mine in the pith of thistles; while many more burrow at the roots of grass, or devour turnip-roots, to the detriment of the crops. The larvæ of the mining moths (*Tineæ*) make sinuous channels between the upper and lower skin of various leaves. These in the perfect form are amongst the smallest and most lovely of all the Lepidoptera. Others, again, feed on clothing and other woollen stuffs, gnawing ragged holes, and when the imago or perfect insect appears

the mischief has been done. So voracious are larvæ that huge oak forests may be in a few days swept bare of almost every vestige of foliage.

Structure of Larva. The body consists of a head bearing biting mandibles for nipping off the edges of leaves, or gnawing amongst decaying timber; a pair of small, short antennæ form appendages on either side; and just behind three simple eyes, or ocelli, on either side, very different from the large compound eyes of the perfect insect. Behind the head lie eleven segments or movable rings. Three of these, close behind the head, correspond to the thorax of the adult, and bear the three pairs of thoracic legs, short and horny, exactly corresponding to the three pair of legs of the butterfly or moth. The other segments bear the pro-legs, or claspers—varying in number from one to five pairs—used for clinging to leaves and other surfaces. In some of the moths the last pair are obsolete as legs, and are developed into a pair of horns, supposed to be for protective purposes, as for instance in the puss-moth. A caterpillar may thus possess sixteen legs, though often there is not the full number.

A very curious form of larva is that producing the insects known as the geometers, so called because of the peculiar gait of the caterpillar, which measures out the surface over which it passes with a regular series of equal strides or loops. Their body is long, but since there are but four pro-legs, they cannot crawl, but by bringing up the hinder-legs advancing the head, and again bringing forward the tail, the caterpillar spans the space to be traversed by a series of looping strides. Hence the Americans call them "span-worms." These larvæ, too, are remarkable for their resemblance—when the head is stretched outwards—to a broken twig, a likeness which undoubtedly secures them from many dangerous foes. Many larvæ are protected by their similarity in colour to the surrounding foliage, and it has been supposed that the pigment from the leaves which the caterpillar eats lends its characteristic hue to its devourer. From the moment of hatching until the final moult, when the caterpillar enters the pupa state, it undergoes a series of from eight to ten changes of the skin. These changes form crises in the lives of larvæ, which, at any rate in captivity, sometimes die during the process.

Pupa. The stage immediately preceding that of the perfect form is usually called, when reference is made to the butterflies, the chrysalis state; but in the case of the moths, the pupa state, though there is no essential difference between the two. In this strange quiescent state the wings, legs, antennæ, and proboscis of the future insect can be seen fully formed and folded tightly within the outer covering. The only signs of vitality are given by wriggling movements of the segmented abdomen, when the pupa is irritated. The hard external covering is useful for resisting the attacks of predaceous insects, though of course not securing them immunity from mice, birds, or moles, which devour them with avidity. The chrysalis of a butterfly is usually angular and gilded. Some are suspended simply by the tail, others have a silken girdle round the middle to keep them fast, while some spin a very slight cocoon. The pupæ of the moths, on the other hand, are dull red, usually smooth mummy-like objects, to which likeness the word pupa or "puppet" doubtless refers. The greater part of these lie simply in the earth, beneath moss or bark, wherever the larva has crawled to effect the change, without any additional covering. Others form a hard cocoon

of the grains of mould, to which consistency is given by means of a gummy secretion furnished by the larva. Many form with this secretion a hard case, the outer side covered with chips of the surrounding bark, which, owing to their similarity to the surroundings, serve as a protection from observation. Others spin a silken egg-shaped cocoon, sometimes flocculent and broken, sometimes formed of yards and yards of silken thread, emitted from the mouth and passed over and under, across and round, until the cell is complete. Amongst the more interesting of these cocoons is that of the emperor-moth, which forms a short tubular exit closed against the entrance of earwigs and other insects by a circular series of fine bristles directed outwards and converging to a point. The principle of contrivance is the same as that employed in the manufacture of lobster-pots; but here the process is reversed, for in this case it admits of a ready egress but prevents any entrance. Moths whose pupa stage is passed within an external cocoon have a double task before them when the time is ripe for an emergence. The pupa itself—as does also the chrysalis of butterflies—splits at the dorsal suture above the thorax, and the moth emerges, ferreting a way through one end of the cocoon, which seems to be softened by moisture from within, and thus escapes. The imago, or perfect insect, having now emerged, climbs to some point of vantage, where the wings, still very small, though completely formed, are allowed to hang downwards, expand and harden in the air. After a few hours they are stiff and ready for use.

Enemies. At no stage in their lives are lepidopterous insects free from the attacks of enemies. In the egg-state they fall a prey to beetles and small birds, and as larvæ they are extremely liable to receive a deadly thrust with the ovipositor (or sting) of an ichneumon. As the ichneumon-grubs grow at the expense of their host, scarcely a tissue in the whole body may remain, save those needful for the carrying out of life-supporting functions. And at last, when the grubs are themselves ready to pupate, and have no further need of their host, they finish up the rest and the larva dies—chiefly because there is nothing left to live. The enemies of the imago, whether butterflies or moths, are numerous. Birds, bats, dragon-flies, etc., pursue and harass them whenever they happen to meet with them. The marvel is that any remain alive to lay eggs and perpetuate the species.

Mimicry. In the struggle to escape detection and capture, all unconscious though it may be, arises the phenomenon alluded to above, and known as protective mimicry. The kindred phenomenon of protective colouring, when the moth or butterfly merely resembles in hue the bark, leaf, or twig on which it rests; also protective resemblance, simply when insects take the form of objects, such as twigs, dead leaves, bits of decayed wood, flakes of white bird-droppings; these are all well known. But protective mimicry means more, it implies the actual mimicking either the form, colour, or habits of some other insect which is either too savage or unpleasant to make it a desirable object of food; as, for instance, the clear-wing moths mimic gnats, bees, wasps, ichneumons, etc. Perhaps the most curious instance is that of the *Kallimas* or dead-leaf butterflies of Northern India, whose upper sides are richly coloured, while the under sides are dull brown mottled and veined with darker colours. So conspicuous a butterfly would not fail to fall a ready prey to foes. If it but settle for an instant, however, the sharpest eye will not detect them. The secret lies in the colour and veining of the

under side. The fly settles, clings to a twig, presses the tails of the under-wings—now folded together against it—and nothing but an old withered leaf remains where but just now was a gaudy butterfly. A species of the genus *Heliconius*, an insect avoided by birds on account of its bitter flavour, is closely mimicked by another butterfly of the genus *Mechanitis*. Though very sweet-flavoured, it escapes unmolested amongst its less agreeable companions. The mimicry involved in the feigning of death by many species of moths is, of course, protective. It has even been asserted that a specimen of the magpie-moth continued to feign death three hours after its head had been severed from the thorax.

Imago or Perfect Insect.

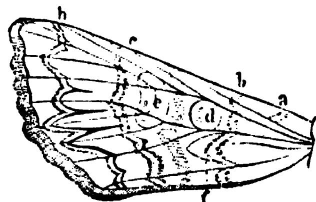
If all the dangers noted above have been passed through with impunity, in due time, at various seasons of the year, the perfect insects—butterfly, or moth, as the case may be—will emerge. These vary in size from 12 inches or more in the expanse of the upper-wings to a quarter of an inch;—the latter being amongst the smallest moths, or Microlepidoptera. We have remarked that the body is divided into three distinct divisions, head, thorax, and abdomen; we must now shortly notice the various structures peculiar to each division. The

Head.

first division of a lepidopterous body is itself divided into four main divisions. The occiput, next to the thorax; the epicranium, bearing the antennæ; and, in some moths, the ocelli or simple eyes; the clypeus, lying in front of the epicranium, just on the mouth-parts, which latter themselves fall into at least five or six distinct structures; the proboscis, long, and capable of being rolled up beneath the labrum when at rest; the labrum, lying at the base of the proboscis, above; the maxillary palpi (absent or rudimentary in the butterflies); the labial palpi, and rudimentary mandibles, aborted in many cases, complete the mouth structures. It is in the structure of the mouth-parts, perhaps, that the butterflies and moths differ most from other insects, and more especially from the fact that the mandibles of the insects have in the Lepidoptera become modified into a long, spirally curled, retractile proboscis, composed of three distinct hollow tubes, soldered to each other along their inner margins. Indeed, it has much the appearance of a double-barreled gun, with a third tube lying below beneath the suture of the upper and larger pair. But it is with this latter alone that nutrition is imbibed, and it is supposed that the other pair may furnish air in addition to that obtained through the spiracular orifices along the abdomen. The ocelli, or simple eyes, resembling those of the larvæ; the small eyes on the upper part of the head of bees and other Hymenoptera, as well as those of other Arthropods, such as we find to the number of from four to eight in the spiders, are not discoverable in the butterflies, but are present in the moths alone. The large compound eye, composed of numerous facets, is, however, present in both sections of the order, lying on either side of the epicranium, just below the point of insertion of the antennæ. Whether they see nature with these "as through a veil," or appreciate every detail as we do ourselves, is a matter of speculation, but not easy of solution. The pair of thread-like, many-jointed organs, which take their origin from the side of the epicranium, just above and within the compound eyes, are amongst the butterflies, with the exception of the family *Hesperiidæ*, thread-like, and abruptly clubbed at the apex. In the latter family they are gradually thickened towards the end, which often terminates in a hook-like point. The moths, however, as their name

Heterocera implies, furnish us with far greater variety in the form of the antennæ; quite apart from the fact that they differ in both sexes of the same species, thread-like, for instance, in the female, pectinate in the male sex, we find at least ten different forms of antennæ amongst members of this section:—*Filiform*, or thread-like, gradually tapering to a point; *fusiform*, broadened from the base onwards to the tip, which is again narrowed; *dilate*, narrow from the base to about one-third its length, then rather suddenly enlarged, and again narrowed at the tip; *ciliate*, clothed with the finest hairs; *setigerous*, each joint furnished with a bristle on either side; *setigerous* and *ciliate*, furnished with both fine hairs and paired bristles; *fasciculate*, each joint furnished with a group or tuft of short bristles, like a small brush; *dentate*, or toothed, each joint produced into a sharp tooth-like process at the side; *lamellate*, where each joint is produced at the margin into a small plate-like prominence; *serrate*, sawlike, each joint produced into a short sharp point at the side, giving the whole antennæ the appearance of a saw, the teeth are not so long as in the dentate antennæ; *pectinate*, each joint furnished with long plume-like hairs, or a pair of such on either side.

Thorax and its Appendages. The second division of the body, like that of the Hymenoptera, is composed of three closely united rings, each bearing beneath a pair of legs, while the posterior pair carry also on their upper or outer sides, each a pair of well developed wings. The *prothorax* bears the fore-legs. The *mesothorax* the mid-legs and fore-wings. The *metathorax* the hind-legs and hind-wings. The legs are not used normally for walking, but are chiefly serviceable for clinging to objects while settling or at rest. They do not call for any special mention; and are not of great account for purposes of classification, except in the butterflies, where in the case of the males of the three families *Nymphalidæ*, *Erycinidæ*, and *Lycænidæ*, the fore-pair are much reduced in size, being in some cases almost rudimentary.



LEFT FORE-WING OF A NOCTUA MOTH.

a, *b*, *c*, *h*, indicate the normal position of the transverse bands. *a*, costal margin; *f*, inner margin; *d*, discoidal spot; *e*, reniform spot.

By far the most important structure in the eyes of the general naturalist, though not necessarily so in the opinion of the expert, are the beautiful membranous, scale-clad pinions. These give the distinctive character to lepidopterous insects, and render them so fascinating to the lover of nature. Broad and ample on the whole amongst the butterflies, more narrowed as a rule amongst the moths—the hawk-moths for instance—they are formed of the finest transparent membrane stretched out between the stiff rib-like nervures, or, more properly speaking, veins, which carry the nutritive fluids from the central system to all parts of the structure. The nerves, as custom will persist in terming them, in the butterflies take a bow-like or ellipsoidal sweep from the base of the wing, forming what is called the *discoidal cell*, whence there branch off to the edges a series of horizontal, almost parallel, slightly divergent, nervures. On the position of these the identification of species is most securely based, though, in order to examine them, the insect must be spoiled as a specimen. In the moths, on the other hand, the *discoidal cell* is less conspicuous, though nervures branch off divergently from the base of the wing in a somewhat similar manner to those of

the butterflies. One of the most remarkable features in the wings of the Heterocera, as distinguishtd from those of the Rhopalocera, is the existence of the frenulum and retinaculum, briefly referred to above as the hook-and-eye arrangement, with which the fore-wing is locked to the hind-wing. As already said, the scales are modified hairs, which take a more and more perfect scale-like form towards the centre of the wing. They lie, in regularly arranged rows, overlapping each other, attached by a short stalk to a small forea or pit in the membrane, to the number of many hundreds of thousands on each insect. Of different shapes and sizes they are themselves, owing to their exquisitely sculptured surface, objects of extreme beauty. And it is to these alone that butterflies and moths owe their manifold tints, from the sombrest browns to the most resplendent metallic greens, golds, and purples.

Abdomen. The third division of the body is composed of a series of nine rings or segments, sometimes, as in the case of many of the moths, tufted along the dorsal line, and also at the extremity. The spiracles, through which the air passes to the tracheal system, lie along the sides of the abdomen, while the organs of reproduction are placed at the extremity in both sexes.

Extinct Forms. Butterflies and moths very rarely occur in the fossil state, owing no doubt to the delicacy of their integuments. Species of both, however, have been found in Tertiary deposits and some few in nodules of amber. The Tertiary beds of the Florissant lake-basin of Colorado have furnished seven species of butterflies, a dozen of moths, and one caterpillar. Two specimens of hawk-moths are known, in one of which is well preserved the spirally-coiled proboscis. Galleries of the leaf-mining *Tineina* have been preserved in leaves from the Chalk, while other Lepidoptera, a few pearl-moths, owl-moths, goat-moths, silk-spinners, burnets, and clear-wings, together with a few species of *Vanessa* and blues, have also been recognised.

THE BUTTERFLIES,—Suborder **Rhopalocera.**

As distinguished from the moths, the butterflies may be recognised as a general rule by their antennæ, which, as suggested by the name Rhopalocera, are slender and abruptly clubbed at the extremity. In some cases, however, in the family of the skippers, these organs are gradually enlarged towards the tip, which is itself often slightly hooked. Butterflies have not, in any case the hook-and-eye arrangement—the retinaculum and frenulum—by which the upper- and under-wings are in the moths interlocked along their inner margins. The fore-legs are not always well developed, and this is particularly noticeable in members of the male sex, forming a reliable character in the broad subdivision of the Rhopalocera into families. Butterflies are mostly diurnal in their habits, flying in the sunshine by day, although a few take wing only towards evening. Their eggs and larvæ differ considerably in many respects from those of the moths, while the chrysalis is seldom enclosed in even the finest network of silk, and in no case is wrapped in a distinct cocoon, nor even buried beneath the earth, very rarely even close to the surface. Usually the chrysalis is angular and blotched and speckled, with gold and silver ornamentation; sometimes it is suspended to a branch or twig by the tail, and

sometimes while fastened by the tail also engirdled with a line of silk around the middle, thus tying in a position horizontal to the plane to which the larva has attached itself. These two characters also have been used for purposes of classification, and the suborder has been divided into Suspensi and Succincti on account of this difference in the attachment of the chrysalis.

Classification. The following broad subdivisions of butterflies may be made:—Firstly, those which have four perfect legs only in both sexes, the fore-pair being rudimentary or undeveloped; while the chrysalis is suspended by the tail without any girdle. These include the family *Nymphalidæ*. Secondly, those having four perfect legs in the male, and six in the female, while the feet of the former have no claws at their extremity; the chrysalis being raised, resting on a leaf or suspended. The *Erycinidæ* represent this group. Thirdly, we have the family of the blues (*Lycænidæ*), in which there are six perfect legs in the female, and the chrysalis is suspended. The fourth group is that of the swallow-tails (*Papilionidæ*), in which both sexes possess six perfect legs, while the chrysalis is attached by the tail and girdled by a silken thread. Lastly, the *Hesperiidæ* agree with the preceding as regards the legs, but the chrysalis is either attached by threads, or enclosed in a loose cocoon. As a rule, mountainous regions are those which abound most in butterflies, although there is a marked exception in the case of the valleys of Tropical America.

The Fritillary Group. The family *Nymphalidæ* includes an extensive assemblage of butterflies, among which are the fritillaries, peacocks, painted ladies, tortoiseshells, and admirals. Here also come the leaf-butterflies, purple emperors, white admirals, Camberwell beauty, and the large high-flying blue *Morphos*. We have also the subfamily *Satyrinæ*, which includes the ringlets, marbled whites, meadow-browns, and graylings, besides many others too numerous to mention. First we may notice, as an example of the subfamily *Danainæ*, the butterfly shown on the lower right-hand corner of the coloured Plate, which is known as *Euplœa harrisii*. In common with several other species, it belongs to a genus of large blue, and brown-winged tropical butterflies, in which the upper surface of the wings is usually spotted with white. At the top left-hand corner of the same Plate is figured the male of the orange scallop-wing (*Cethosia biblis*), which may be taken as a representative of the subfamily *Nymphalinæ*. It is an inhabitant of North-Eastern India. Its black and spiny larvæ have the body banded with red and yellow, and the head surmounted with a pair of horn-like processes.

A better-known group are the fritillaries (*Argynnis*), which are mostly confined to the temperate districts of the Northern Hemisphere. In this genus, the British silver-washed fritillary (*A. paphia*) is amongst the finest representatives of a large number of orange-red or fulvous insects whose hind-wings on the under side are spotted, spangled, or slashed with silver upon a dusted green ground. Not uncommon throughout England, it occurs in abundance in the glades of the New Forest, where the larva feeds on the dog-violet or wild raspberry. The dark green fritillary (*A. aglaia*), a near relative, frequents the southern grassy downs along the margins of the cliffs, or sports in the fern-embroidered dells of the lake-district valleys. The high brown fritillary (*A. adippe*), a rather smaller form, whose hind-wings, as are those of the last-named species, are spotted with silver discs, while

those of the silver-washed are slashed obliquely towards the lower angle. The Queen of Spain (*A. lathonia*), a much rarer insect, and the two elegant little pearl-bordered fritillaries (*A. euphrosyne* and *A. selene*) are also. British. The greasy fritillary (*Melitæa aurinia*) brings us to another genus, the members of which closely resemble those of the former, but are as a rule smaller. So many figures of all the British species have been published, that detailed description is superfluous. The greasy fritillary inhabits low-lying marshy meadows in various localities in England, where the larvæ feed on the plantain. The heath fritillary (*M. athalia*) is a very similar though very local species; while the glanville (*M. cinxia*) is rare in Britain, where it is confined to the Isle of Wight. Many handsome species of this genus are found in all the more northern regions of the world, but undoubtedly the most numerous occur in the South-Western United States. The magnificent fritillary *A. childreni*, which measures nearly 5 inches from wing-tip to wing-tip, is indigenous to the Himalaya. Closely allied to the fritillaries is the map-butterfly (*Araschnia levana*) of Central Europe. It presents two very distinct forms, one of which (*A. levana*) appears in the spring, the other (*A. prorsa*) later on in the summer, while an intermediate form (*A. porima*) is also recognised. The form known as the spring brood, figured on p. 90, is fulvous red with scattered black spots, presenting also three white spots near the tip of the wing. The summer brood (Fig. 4) has black wings with a red marginal line, having besides a broad broken white bar across the wings and some white spots near the margin. The larvæ feed on the nettle in June and September. The insect, though common on the Continent, has not been taken in England. The curiously-shaped butterfly known as the comma (*Polygonia c-album*), was formerly much more common in England than it is at present. The wings are rufous with black spots, and very strongly emarginate along the edges, and angular. The white c-shaped spots on either hind-wing beneath render it not easily mistaken for any other British species.

The handsome butterflies known as tortoiseshells (*Vanessa*) are amongst the most widely distributed of the family, though confined to the Northern Hemisphere. Most inhabit the more temperate regions of Europe, Asia, and America, although a few occur in India, Ceylon, the Malay Peninsula, and Mexico, The caterpillars feed on plants and trees, and are usually dark and spinous. The chrysalis, angular and distinguished by its brilliant lustre, is suspended by the tail,and forms a beautiful object. The large tortoiseshell (*V. polychloros*), so common in woods in England, is usually found settling upon the trunks of trees, in summer and autumn. The wings are rich fulvous-red, blotched and margined with black, and having a narrow broken vein of blue just before the outer fringe. The larvæ feed on the leaves of various trees, and the chrysalis is pale pink relieved with golden blotches. The small tortoiseshell (*V. urticæ*), whose jet-black spiny larva feeds on the nettle, is amongst the commonest British butterflies. The peacock butterfly (*V. io*), well known on account of the large eye-like blotches on the upper and under-wings, is figured in all its stages in the illustration on p. 86. The larvæ also feed upon the nettle; and the insect is found throughout Europe and Northern Asia as far as Japan, but not in Northern Africa. One of the handsomest, and at the same time of the rarest, of British butterflies,

is the Camberwell beauty (*V. antiopa*). Its large angular wings are rich brown above, with a broad yellow border, enclosing on its inner margin a row of blue spots.

In the tropics the place of the preceding genus is taken by *Junonia*, the members of which are not perhaps so richly coloured as the tortoiseshells. They occur all over Eastern and Southern Asia, and are also found in North and South America, the Oriental countries, and Africa. The caterpillars are spinous, as are those of the two tortoiseshells. A figure of the beautiful, although dark-coloured, Swinhoe's tortoiseshell (*J. swinhoei*), is given at the lower left-hand corner of the coloured Plate. As an example of the genus *Pyrameis*, we may take the red admiral (*P. atalanta*), which is a well-known and richly-coloured British butterfly, appearing in the autumn in woods, and also in orchards where it feeds upon the juices of decaying apples. The large black wings with a scarlet band across the upper, and a margin of the same colour around the lower, together with the group of pure white blotches towards the tip of the former, render it a very conspicuous insect. When, however, the wings are closed, the mottled black and brown render it almost invisible. The larvæ are black and spinous, and feed upon the common nettle; and the species is found all over Europe and North Africa, North and West Asia, and North and Central America. In many other regions its place is taken by some very closely allied forms. In the painted lady (*P. cardui*), of which the caterpillars feed upon the thistle, the wings are orange-red, black-spotted, and black-tipped, the latter area bearing a group of white spots. It is abundant in almost every country of the world, except the Arctic regions and South America. Nearly allied are the porcelains (*Cyrestis*), which measure from 2 to 3 inches across the wings, and are found in India, the Malay Archipelago, and a few in West Africa and Madagascar. The sooty-veined porcelain (*C. thyodamas*) represented on the coloured Plate, No. 3 from the lower right corner, is an inhabitant of Madagascar. Of the genus *Limenitis*, the large white admiral (*L. populi*) occurs in Central Europe, South Scandinavia, and Finland, but has not been met with in the British Islands or in Holland. It is nearly twice the size of the English white



GROUP OF BUTTERFLIES.

1, Peacock butterfly; 2, The same just emerged; 3, The caterpillar; 4, The chrysalis; 5, Meadow-brown; 6, The caterpillar (nat. size).

admiral (*L. camilla*), its wings being brown with a row of lunate orange marks near the hinder margin of the lower wings. The arrangement of the white bars on the upper wings is the same as that of the British form, but these are almost obliterated in the male sex. The under side is of a beautiful orange-yellow colour, broken with white, and elsewhere suffused with various shades of purplish and bluish grey.

Closely allied to the admirals are the mango-butterflies (*Euthalia*), which are almost entirely confined to India, the Malay Peninsula, and the adjacent islands. They measure from 2 to 4 inches across the wings, and the larvæ feed on the leaves of the mango. An illustration of the black mango-butterfly (*Eu. lubentina*) will be found on the coloured Plate, No. 2 from the top right corner. The emperors (*Apatura*) are widely distributed over the world, except in Africa. Two species alone are found in Europe, and these are much more brilliant insects than the majority of the temperate species. The caterpillars are not hairy, but smooth, and bear a pair of horns on the head, as also does the chrysalis. In Britain the purple emperor (*A. iris*) is confined to the southern counties of England. Its strong purple-shot, white-banded wings, 3 inches in expanse, carry it with a grand sweeping flight far above the highest oak-trees, whence it descends, alas for imperial predilection, to a savoury banquet of putrid flesh, set out in some suitable locality. The caterpillar feeds upon the sallow, and the perfect insect appears in July.

Passing over many genera, containing some of the loveliest foreign forms, we reach the sub-family *Morphinæ*, in which the caterpillars are remarkable for their bifurcate tail and notched or bifid head. The species of the typical genus are giant butterflies of almost every hue, the most conspicuous being of a dazzling metallic sky-blue. Their long, satiny wings bear them aloft far out of the reach of the collector's net. In the annexed illustration is figured, from the under side, the resplendent ptolemy (*Morpho neoptolemus*). The upper side is rich black brown, with broad transverse blue bands, shot with delicate lilac across both wings. A pair of white spots are conspicuous on the tip of the fore-wing.



RESPLENDENT PTOLEMY (nat. size).

We have now to briefly notice a number of much less brightly coloured

butterflies, many of which will be familar to most readers forming the subfamily *Satyrinæ*. They include the ringlets (*Erebia*), speckled-woods (*Pararge*), marbled whites (*Melanargia*), meadow-browns and heaths (*Epinephele* and *Cœnonympha*), wall-browns (*Satyrus*), graylings and common wood-ringlet (*Hipparchia*), and many others. The caterpillars are mostly smooth, fusiform, and green, having two horns on the head and a bifurcate tail. They feed on grasses. These butterflies fly somewhat feebly over meadows, downs, highlands, and heath districts. As an example of the typical genus *Satyrus* may be taken the common British wall-brown (*S. megæra*). Here the wings are rufous brown, spotted, speckled, and streaked with black, having also a single eye-like spot on the upper-wing at the tip, and three on each lower-wing, near the margin. As a rarity, collectors prize a specimen in which the fore-wing spots are bipupilled, or having twin pale centres. Of the graylings (*Hipparchia*), the British *H. semele* is abundant in the heath and mountainous districts of England. Owing to its beautifully grey-mottled under-side, it is absolutely invisible when settled upon rocks or amongst the grey stones of the moorlands. The nearly allied meadow-browns and heaths (*Epinephele*), which do not present a very great number of species, are most abundant in the Mediterranean region and Western Asia. They fall into two groups, of which *E. janira* is a good example of the one, while *E. tithonus*, the large heath or gatekeeper, illustrates the other. The former, which is the commonest of British butterflies, abounds in fields and meadows in the summer, ceasing to fly the moment the sunbeams are obscured by a passing cloud. Specimens with pale patches on the wings are valued by lovers of varieties. The upper figures on p. 86 represent the adult and caterpillar.



WALL-BROWN (nat. size).

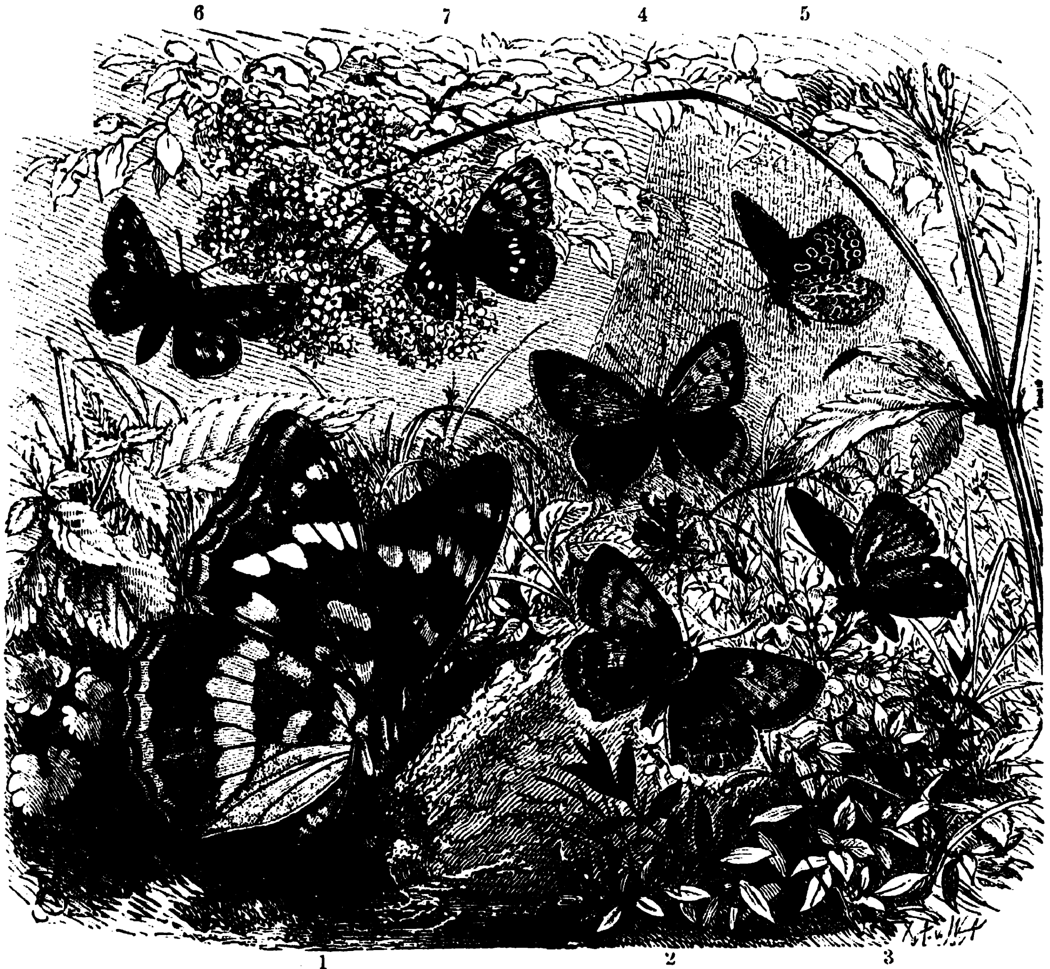
Family *ERYCINIDÆ.*

This small family, of which the characters are given on p. 86, includes species chiefly found in the tropics. *Erycina aulestes* of Brazil is peculiar in having the mid-wings produced into a tail-like projection. As an example of the family we may take the Duke of Burgundy butterfly (*Nemeobius lucina*), an illustration of which is given in the coloured Plate, No. 2 from the lower right corner. Its brown, yellow-spangled wings once earned for it a place amongst the fritillaries. It is, however, the sole British representative of a family whose members are so abundant in Brazil.

THE BLUES AND COPPERS,—Family *LYCÆNIDÆ.*

This large family, represented by many small brightly-coloured insects, includes the blues, coppers, hairstreaks, and many others. Of the hairstreaks

(*Thecla*) the purple hairstreak (*T. quercus*) is a familiar example. This butterfly has the wings brown black, shot with purple, and abounds all through Europe wherever oak forests exist. It flits round the foliage, laying its eggs, and resting on the leaves, and is a common British butterfly. The green hairstreak (*Th. rubi*) is a smaller species than the rest, with a bright green under side, and is not uncommon in some districts flying around bramble-bushes in summer. In the allied genus *Polyommatus*, we mention the large copper (*P. dispar*) as one would speak



GROUP OF BRITISH BUTTERFLIES.

1, Large white admiral ; 2, Golden rod copper, female ; 3, Male of same ; 4, Small copper ; 5, Azure or Clifden blue ; 6, Silver studded skipper ; 7, Duke of Burgundy.

of a departed friend, for, although formerly abundant in the fens of Cambridgeshire and other counties, it has nôt been seen alive for over half a century in Britain. The small copper (*P. phleas*) is, however, very abundant both in England and on the Continent. It is shown in No. 4 of the above illustration. Of the golden-rod copper (*P. virgaureæ*) figures are given in Nos. 2 and 3 of the same illustration. This species is abundant on the Continent, though unknown in Britain. It flies in July and August, and the larva feeds on the golden-rod. The elegant little butterflies known as blues (*Lycæna*) have the upper side of the

wings in the male sex of various shades of blue; those of the female, on the other hand, being usually brown, shot with a bluish or purple tinge. The larvæ are wood-louse-shaped, and feed mainly on grasses of various kinds. The common blue (*L. alexis*) is one of the most abundant of British butterflies, whose white-fringed, pale blue upper side and speckled under side, in the male, are familiar to



GROUP OF TROPICAL BUTTERFLIES.

1, Scarce swallow-tail, with larva and chrysalis; 2, Map-butterfly, spring brood; 3, Larvæ; 4, Summer brood; 5, Chrysalis of same.

everyone. The male is figured on the top right corner of the coloured Plate. Of the many blues found in England, such as the silver-stud, the chalk-hill, the holly blue, and the little or Bedford blue, the Clifden blue (*L. adonis*)—the azure blue of many authors—is the most beautiful. It occurs not infrequently, though locally, upon the Chalk downs of the southern coasts, and in some other localities. A figure of the male is given in the illustration on p. 89. The wings are of a much brighter blue than those of *L. alexis*.

THE SWALLOW-TAILED GROUP,—Family *PAPILIONIDÆ*.

This immense family includes the giant *Ornithoptera*, or bird-winged butterflies of the tropics, the swallow-tails, Apollo butterflies, whites, brimstones, and many others. As mentioned above, this family and the next are characterised by the possession of six perfect legs in both sexes. The chrysalids of the present family are suspended by the tail and girdled with a thread of silk. The largest of the butterflies (*Ornithoptera*) belonging to this family measure nearly a foot across the expanded wings. The typical members of the family are the swallow-tails (*Papilioninæ*), which are large butterflies characterised generally by the presence of a long tail-like process to the hind-wings. Occasionally, however, as in the female of *Papiliomerope*, these appendages are wanting. The two uppermost figures of the illustration on p. 90 exhibit the scarce swallow-tail (*P. podalirius*), which is a large, strong insect with triangular front wings, and a long tail at the lower angle of the hinder pair. In colour the wings are pale yellow, with oblique transverse black bars. This splendid butterfly, although common in Southern Europe, North Africa, West Asia, and Persia, is only very rarely taken in England. The larvæ feed on leaves of the sloe, apple, plum, and other orchard trees. The common swallow-tail (*P. machaon*) was formerly very abundant in the fen districts of England, but since these have been drained it has become scarcer. The four wings are sulphur-yellow, black at their base, with black veins, and hinder pair of the same colour, with a band of blue towards the margin, and a red spot on the inner angle, close to where the tail springs. The larva feeds on the common carrot. This species has a very wide range, occurring in the Kashmir Himalaya. Of the royal swallow-tail (*Tinopalpus imperialis*), from Sikhim, a figure is given in No. 2 from the top left-hand corner of the coloured Plate. The females are less brilliantly coloured than the males, and have a pair of tails to each hind-wing.



BLACK-VEINED WHITE, WITH LARVA AND CHRYSALIS.

The whites, clouded yellows, orange-tips, brimstones, etc., represent the second subfamily (*Pierinæ*) of this assemblage, in which there are no tails to the hind-

wings. One of the rarest British butterflies is the black-veined white (*Aporia cratægi*), shown in all stages of development in the illustration on the preceding page. Its caterpillar feeds on the leaves of the blackthorn and other bushes. Of a foreign representative of the group, the black-tailed sulphur (*Dercas verhuelli*), an illustration is given in the coloured Plate, No. 2 from the left lower corner. It is nearly allied to the common brimstone butterfly (*Rhodocera rhamni*), so abundant in spring in English lanes and hedgerows.

The Skippers,—Family *Hesperiidæ*.

This family differs from all the others in the broad, thick head; the hind tibia (with some few exceptions) being armed with two pair of spurs. There are hundreds of species belonging to this interesting family, the majority being indigenous to South America. Many are distinguished by their powerful build, brilliant colours, and long-tailed hind-wings. The European species are all small, and more or less sombre coloured, averaging about an inch across the wings. In the puss-tailed skipper (*Goniurus catillus*) of Brazil, the front-wings are brown on the upper side, with five or six pale yellow spots; and the hind-wing also brown, and ending in long, broad flat tails, quite as long as the hind-wing itself. The antennæ are strongly hooked at their apex. *Telegonus alardus*, from Venezuela, has large wings, 2 inches across, brown, shot at their base with blue and green, but only very slight tail-like prominences on the hinder-wings. To *Pamphila* and the following genera belong all the small, quick-flying butterflies, known as the skippers, properly so called. When at rest many of these insects raise the upper-wings, leaving the lower ones horizontal, a habit not unknown among butterflies of other families. The Lulworth skipper (*P. actæon*) is a rare, or rather local, small brown skipper, confined in England to a few spots along the south coast. Amongst others are *P. sylvanus*, the large skipper, *P. linea*, the small skipper, and *P. lineola*, the scarce small skipper lately added to the British list. The dingy skipper belongs to another genus (*Nisoniades*), as does the chequered skipper (*Cyclopides*). The grizzled skipper (*Hesperia malvæ*) is a black or brown butterfly, with white spots on the upper side, common in England in summer. The silver-studded skipper (*H. comma*) is confined to some of the midland and southern counties of England, though abundant on the Continent. Figures of this butterfly will be found in the illustration on p. 89, and on the coloured Plate, No. 3 from the top right corner.

The Moths,—Suborder **Heterocera**.

Since limitations of space will only admit mention of a few of the genera and species of butterflies, we pass on to the moths, in which the antennæ are of many different forms, but never distinctly clubbed. Moths are vastly more numerous—both in genera and species—than butterflies; and, as already observed, are for the most part nocturnal insects. The other distinctive features having been already mentioned, we proceed to the first family of the group.

Emperor-Moths,—Family *Saturniidæ.*

The splendid moths included in this family are probably amongst the most beautiful, as they certainly are amongst the largest, of all known Lepidoptera, ranging in size from the atlas moth (*Attacus atlas*), which measures a foot at least in expanse of wing, down to the English emperor-moth, of 2 or at most 3 inches in diameter. They do not, however, vary so very much in the comparative beauty of their richly coloured ocellated wings. The larvæ, too, are not only of remarkable beauty, but have great commercial value; for it is from members of this family that China and Japan obtain vast quantities of a strong, though less expensive silk than that produced by the ordinary silk-worm. The former are the oak silk-moth of China (*Saturnia pernyi*), and its near relative *Antheræa yama-mai* of Japan. In all their stages these lovely insects are remarkable, differing widely in their general characters from the majority of



HAWK-MOTHS.
1, Eyed hawk-moth and larva; 2, Humming-bird hawk-moth and larva. (Nat. size.)

moths. The larvæ, with their clear rich green velvet bodies, deeply cleft into separate, well-marked segments; their rounded warts, golden, rose-coloured, and sky-blue, emitting long sinuous hairs, the latter, sometimes enlarged at the extremity, cannot fail to attract attention both for their unusual aspect and their beauty. When this stage is past, and the insect reposes in the large, leathery, sombre-brown cocoon, there is no lack of interest. The mouths of these cocoons, as noted at the commencement of the chapter, are fashioned for the better security of the slumbering pupa. No earwigs, beetles, or other prowling enemy can find its way into the cocoon to destroy the inmate, though the moth can readily emerge as soon as the outer shell of the enclosed pupa has been burst. For with a subtle ingenuity, no less wonderful because instinctive, the larva has carefully provided

against these contingencies. It has arranged stiff, springy bristles round the orifice, each pointing outwards, gathered in at their tips, so that unwelcome visitors cannot gain an entrance. But beyond all these interesting features, the perfect insects are themselves sufficient to enlist our admiration. The enormous, strong fore-wings with prominent anterior angles; the rich browns, purples, and greys in every shade and gradation; the large crescent-shaped or eye-like blotch on both fore and hind-wing render the members of this family not easily to be mistaken for any other lepidopterous insects. True, the eye-like blotches recall to mind those of the peacock-butterfly, but the stout, woolly bodies, the plumose antennæ, and the feathered legs of the emperor-moths will show clearly enough that the resemblance is but superficial, and that there is no close relationship between them. The males fly swiftly, with a somewhat erratic flight in the broad daylight; and if the female, held captive in some receptacle, be placed in the open woods, many of the former sex will eagerly gather round the cage, and thus themselves fall victims to the net of the naturalist. There are many varieties included in the family *Saturniidæ*, though mention can be made of only a few. The common emperor-moth (*Saturnia carpini*), one of the dwarfs of the family, is abundant in England, where, in the heather-districts, the beautiful emerald larva, studded with rose or golden-yellow warts, may often be discovered wandering over some open sandy space or footpath. It is, however, at times scarcely distinguishable as it nestles amongst the heather-stems, since the rosy warts on the back and sides assimilating closely with the pink heather-blossoms secure it from observation. The moth itself—smaller and darker in the male sex —is of a deep purple brown. The fore-wings, richly variegated with greys, are bordered with a snow-white fringe, while the hind-pair are orange margined with brown. Both fore and hind-wings bear a black eye-like blotch, ringed with a narrow line of blue in the centre. The tough and dry empty cocoon may often be seen spun up amongst the heather-stems. The common emperor is found all through Europe and in Northern and Western Asia, while a much larger form, the peacock-moth (*S. pyri*), is not uncommon in Southern Europe, and has been caught as far north as Paris. Passing on to the Chinese oak silk-moth (*S. pernyi*), we find that its chief interest lies in the fact of the commercial value of its cocoon; a value which has not been fully recognised for more than thirty or forty years. The Abbé Perny, from whom it derives its scientific name, was the first to introduce it to the notice of European silk-merchants, and from him we have a description of the method adopted by the Chinese in breeding and rearing the larvæ and winding off the silken treasure. Coppices of dwarf oak-trees are cultivated, the earth is smoothed and cleansed with great care beneath the trees, while attendants are always at hand to shift the larvæ from one bush to another, or restore them to the foliage when they have fallen to ground. The best of the cocoons from last year's cultivation are placed in a carefully regulated temperature, and the moths are hatched off exactly at the season when the oak-leaves are beginning to be ready for the larvæ. This will be about the month of April, when the females are laid in wicker trays where they may deposit their eggs. Soon, within ten days, the tiny larvæ creep forth and mount the oak-twigs laid in the trays for their reception. Carried forth to the tender oak-foliage, they

quickly commence to feed, while the keepers are always on the watch to protect them from insect-vermin, birds, etc., which, if permitted, would soon clear off the whole plantation. Forty-five days at the outside, and the larvæ are full-fed; they then spin their cocoons, pass into the pupa state, and the winding off of the silken harvest begins. The largest cocoons are selected and set aside for the breeding of larvæ for another year. The rest are exposed to a high temperature which destroys the pupæ within. Boiling water—in which the earthy salts of buckwheat ashes cleaned for this purpose have been dissolved—renders the cocoon fit for being unwound. The silk is wound off in strands,—five, six, or eight in number,—a single strand from each cocoon, according to the strength of thread required. The silk thus prepared is much stronger than that from the silk-worm moth, though it is neither so fine in texture nor so valuable. The Japanese oak silk-moth (*S. yama-mai*) is closely allied to the above, and the process of cultivation of the insect much the same.

THE SILK-SPINNERS,—Family *BOMBYCIDÆ.*

The only species belonging to this family known in Europe is the one mentioned above as the true silk-worm moth (*Bombyx mori*). This insect has become acclimatised in many parts of Southern Europe, where, as in China, it is cultivated for its silken produce. The larva is itself not remarkable, save perhaps for its resemblance to the caterpillars of the hawk-moths, with its smooth naked skin, and short erect tail. It is, however, by far the most valuable caterpillar yet discovered. Ages ago, from two to three thousand years before the Christian era,—if Chinese records be reliable,—this larva was well known in the far East, and already silk-culture was a well-established element in the national industry. History relates how the eggs were first brought to Europe, in the reign of the Emperor Justinian, by Persian monks, concealed in their hollow bamboo staves; and from these silk-culture in Europe took its origin. It was, at any rate, carried on at Constantinople in A.D. 520. The Arabs introduced the industry into Spain, whence it spread in the twelfth century to Sicily, and thence to Italy and all the south of Europe. So far as England is concerned, both James I. and George I. endeavoured to introduce the cultivation of the silk-worm for commercial purposes, but without success. The actual mode of cultivation and preparation of the cocoon differs in no very essential feature from that of the oak silk-moth, save that it is usually conducted under cover in well-ventilated rooms; the wicker trays of silk-worms being arranged in rows one above the other on light bamboo racks.

THE HAWK-MOTHS,—Family *SPHINGIDÆ.*

The large moths included in this family are either diurnal or subnocturnal in their habits, flying powerfully both in the daytime or just before nightfall. Amongst other characteristics, the antennæ are gradually thickened towards the tip, which terminates in a hook. The fore-wings are elongate, narrow, and usually pointed towards the apex; while the hind-wings are comparatively of small size.

The larvæ are smooth, generally with a horn on the last segment of the abdomen. They make no cocoon, but the pupa lies in the earth, into which the larva burrows before the transformation takes place. As is the case with almost all, they are protected by their colouring, which assimilates to that of the food-plant. These fine insects are divided into several subfamilies and many genera.

As the type of the subfamily *Acherontinæ*, may be taken the well-known death's-head moth (*Acherontia atropos*), which is by far the largest of British moths. It is a very stout, bulky insect, with strong, broad wings; its thorax having on the upper side a pale mark, which bears some small resemblance to a human skull, whence it derives its scientific and trivial names. The fore-wings are dark plum-colour, lined and spotted with the yellow; the hind-wings yellow, with two sinuous transverse bars of black; and the body dark plum-colour, with black transverse lines, and a yellow patch at the side of each segment. The most remarkable fact about the moth is that it is capable of producing an audible squeak. Whether this is

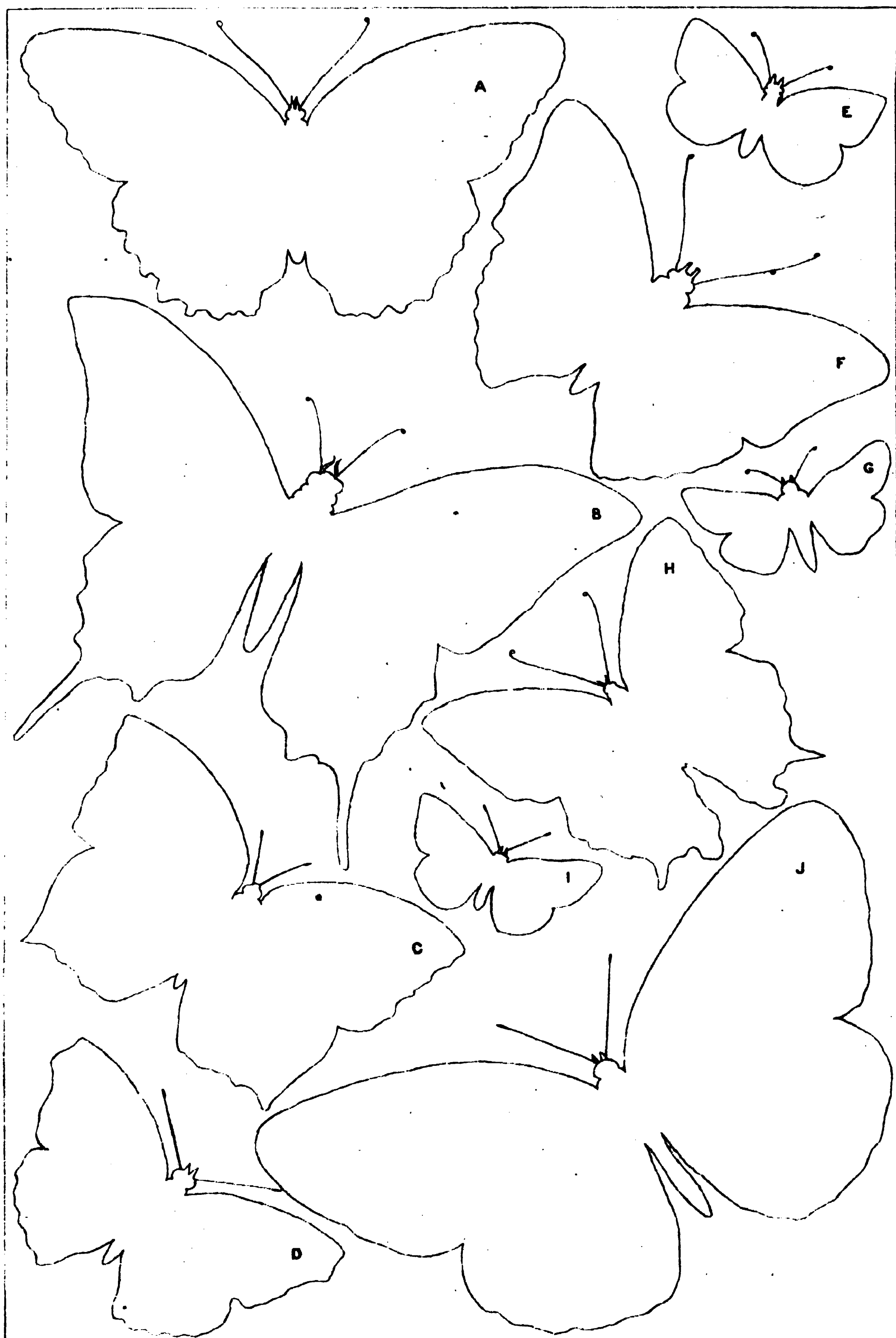


ADULT AND CATERPILLAR OF SPURGE HAWK-MOTH, WITH ICHNEUMON-FLY.

produced, as was formerly supposed, by the friction of the palpi against the coiled proboscis, or by the sudden passage of air—previously drawn into a cavity in the stomach—through the œsophageal orifice and the proboscis, acting upon a cleft at the extremity of the latter, is not certain. If, as has been asserted, the squeak does not abate even on the decapitation of the moth, the air-passage theory suffers a shock, and evidently does not entirely account for the noise. The cleft at the end of the proboscis would perform a somewhat similar function to that of the tongue in a penny trumpet, the reed in certain wind instruments, or the orifice in a whistle-pipe. The handsome larva (green, with large, pale yellow, swollen anterior segments, and yellow, black-speckled oblique stripes across the sides), with its spinous tail, may be sometimes discovered on the jasmine and in potato-fields. Not unfrequently, the large pupa tumbles from its friable earthen case, when the potato crop is dug. The moth flies strongly at night, feasting usually upon the sap oozing from the trees. It does not, however, hesitate to rob the hive of the honey-bee, and apparently without molestation.



TYPICAL BUTTERFLIES.



A. **Orange Scallop Wing,** *Cethosia biblis* **(male).** *B*. **Royal Swallow Tail,** *Tinopalpus imperialis* **(male).** *C*. **Black-tipped Sulphur,** *Dercas verhuelli*. *D*. **Swinhoe's Tortoiseshell,** *Junonia swinhoei*. *E*. **Common Blue,** *Lycæna alexis* **(male).** *F*. **Mango Admiral,** *Euthalia lubentina*. *G*. **Silver-studded Skipper,** *Hesperia comma*. *H*. **Sooty-veined Porcelain,** *Cyrestis thyodamas*. *I*. **Duke of Burgundy,** *Nemeobius lucina*. *J*. **Harris's Snowflake,** *Euplœa harrisii* **(female).**

To the typical genus of the second subfamily *Smerinthinæ* belong several well-known British species, among which the eyed hawk-moth (*Smerinthus ocellatus*) is figured on p. 93 as an example. This moth is characterised by its angular, slightly scalloped fore-wings and rose-coloured hind-wings, each bearing an eye-like black spot, ringed with blue, near the inner angle. The larva is delicate green, its skin rough with minute warty points, with a series of oblique



OLEANDER HAWK-MOTH, WITH LARVA AND PUPA (nat. size).

white stripes across the segments at the sides, and a short, sharp tail. It feeds on the willow and other trees, assimilating well in colour with the leaves and their oblique veins; while the moth, hanging with half-closed wings, closely resembles a half-detached withered leaf. The insect is found thoughout Europe and Northern Asia. One of the largest and most beautiful of the tribe is the oleander hawk-moth (*S. nerii*). In this species the fore-wings are rich green, veined with white, having towards their base a triple, transverse rose-coloured bar, whose posterior

arm runs along the hind-margin of the wing to the thorax. The hind-wings, thorax, and abdomen are green. The larva is green, with a pale band and numerous white speckles on the sides. The first three segments are suffused with yellow, and the third bears a large bilobate blue spot, outlined with black, on either side. The moth occurs throughout Europe, Africa, and Southern Asia; but neither larva nor perfect insect are often taken in England. The caterpillar feeds on the oleander and periwinkle in summer. Another beautiful, though small species, is the elephant hawk-moth (*Chærocampa elpenor*), which typifies a third subfamily (*Chærocampinæ*). In this species the front-wings are green, margined and veined with delicate rose-colour; the hind-wings black, with rose-coloured borders; the thorax and abdomen of the same tint of green, with a central rose-coloured band along the back, another at the sides; while the two last segments of the abdomen are rose-coloured. The larva is black, with three eye-like spots at the sides of segments three, four, and five, which are much enlarged, having also a rose-coloured band along the sides. It feeds on fuchsia, bed-straw, willow-herb, etc., and is common in Europe and Northern and Western Asia in June. To the same subfamily belong the members of the genus *Deilephila*, which have a world-wide distribution, although specially common in Southern Europe; among these, one of the commonest on the Continent being the spurge hawk-moth (*D. euphorbiæ*). Although the adult is rare in England, the caterpillar has been observed in some numbers in Devonshire, feeding on the sea-spurge. The fore-wings are grey and rose-colour in blended tints, with a large dull-green spot at their base, and an oblique submarginal band of the same colour, besides two smaller crescent-shaped spots towards the tip; the hind-wings delicate rose, with black base, a deep crimson transverse bar, followed by a narrower black one a little beyond the middle; and the thorax and abdomen green, the latter with white sides. The caterpillar is black, speckled with yellow, having a dorsal rose-coloured central line, a row of yellow spots along either side, and another below of red and yellow spots blended. It feeds on the sea-spurge from July to September. In the figure on p. 96 the larva is repelling the attack of an ichneumon, by ejecting noxious fluid into its face.

The pine hawk-moth (*Sphinx pinastri*) belongs to the typical subfamily (*Sphinginæ*), and is a dull grey species, scarcely to be discerned as it rests on the similarly tinted bark of the pine-trees on which the larva feeds. The moth lays her pale green eggs upon the pine-needles, and in about a fortnight the larvæ emerge, and at once attack the needles. They have occurred in such abundance on the Continent as to ruin whole forests of pine-trees, to the extent of many thousand acres. Although the moth is common throughout Europe, and several specimens have been taken in England, it is very doubtful whether a genuine British-bred specimen has ever occurred. The larva, which changes to a pupa beneath the earth, is green, with narrow longitudinal bands of red and white; these lines being naturally a great protection amidst the longitudinal lights and shades of the pine-needles. The species is figured on p. 77.

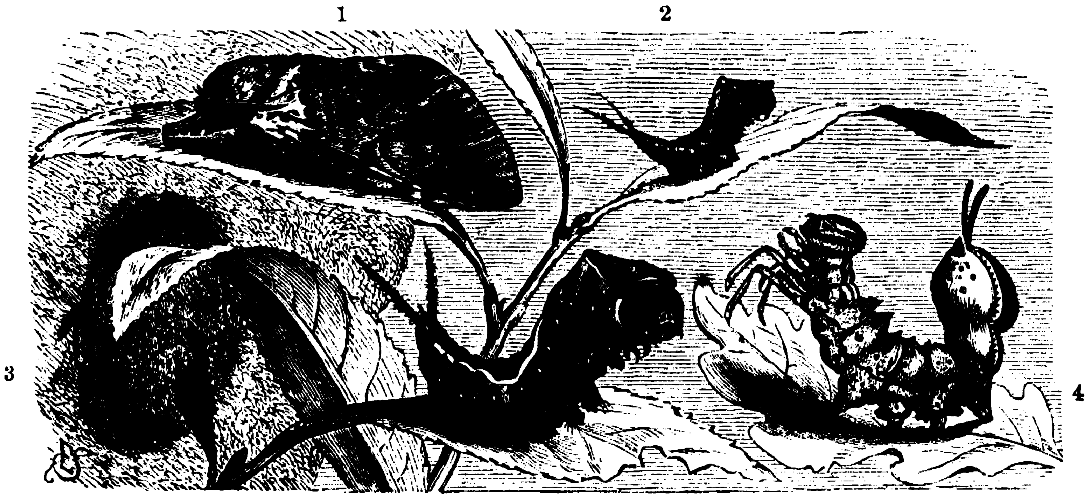
Yet another subfamily (*Macroglossinæ*) is represented by the humming-bird hawk-moth (*Macroglossa stellatarum*), shown in the figure on p. 93. This small and swift species, which hovers with a darting, fluttering course over flower-beds in the sunshine, is double-brooded, and occurs almost all the year round. It has

often been mistaken for a humming-bird, whose flight it closely resembles, while travellers familiar with the latter mistake the long proboscis from which the moth derives its generic name for the slender bill of the humming-bird. The fore-wings are dark black-brown, and the hind-wings pale copper-red. The sides of the abdomen are blotched with white, its extremity being thickly tufted. The larva is green or pinkish brown, with a pale stripe along the sides; and feeds on the lady's bed-straw. The autumn brood of larvæ hibernate in the pupa state, the perfect insects emerging in the spring.

THE PROMINENTS,—Family *NOTODONTIDÆ.*

These moths—which are of moderate size, with stout, hairy bodies, long, ample wings, sometimes with a tooth-like tuft of scales on the inner margin—are very similar in general appearance to members of the family of owl-moths (*Noctuidæ*). The antennæ are usually pectinate in the male, and simple in the female, but in some genera comb-like in both sexes. The larvæ, which in many species assume strange abnormal shapes and attitudes, are smooth and shiny, and without the last pair of claspers. In some cases the terminal segment bears a pair of tail-like processes, which can be raised or depressed, spread widely apart, or closed at pleasure. When full-fed, the larva forms a tough cocoon, covered with chips of wood or other débris, in which it turns to a pupa. The perfect insects fly at night, and may sometimes be found during the day resting on the trunks of trees, palings, or other suitably coloured objects. A common British representative is the buff-tip (*Phalera bucephala*), although it is more often met with in the larval state than adult. Yellow-and-black-spotted, the young larvæ may be found together, feeding gregariously upon elms and other trees. The silver-grey wings, streaked and barred with rich browns, their tips painted with a patch of pale yellow, appear when closed, as the moth rests on the grey bark of a tree, exactly like a short grey stick with the top bevelled off on either side, and partially decayed. The puss-moth (*Dicranura vinula*), is another common British species often found on poplar trees in the larval state, though the perfect insect is seldom met with. The latter has white fore-wings, tinged and marked with grey; the thorax being spotted with black. The compressed, globular, dull red egg is laid in the summer months on the leaves of the poplar or sallow, and the tiny caterpillars are at first quite black, but become greener as they grow older. When full grown, they assume, at rest, the characteristic position represented in the accompanying illustration, whence they derive their name of puss-moths, from some fancied resemblance to a cat. The bifurcate tail emits thin red filaments from the apex of each branch when the larva is irritated; the colour being then bright green, with a red-brown or chocolate-pink patch margined with white behind the head, narrowed and then broadened at the sixth segment, and narrowing again to the tail. The cocoon is very tough, formed in some crevice of the bark gnawed into a convenient cup by the strong jaws of the larva. On the top are glued the chips thus obtained, and, with bits of lichen added, it almost defies detection amongst the surrounding knobs and rounded bits of bark. The species is common throughout Europe and Asia. The caterpillar of the lobster-moth (*Stauropus fagi*) resembles nothing to be found in nature save

those of the closely allied species, as may be seen from the illustration. The moth is found, but not commonly, throughout Europe, and the larva feeds in July upon the oak, birch, and other trees. It is supposed that the extraordinary attitude, with head and tail erect, has proved beneficial in warning off noxious enemies. Another type is represented by the figure-of-eight moth (*Diloba ceruleocephala*), in which the fore-wings are lead-colour, with a pair of white spots which sometimes bear a very close resemblance to figures of eight. The larva is blue-green, with a central yellow stripe along the back, another below the spinners, while each segment bears a number of black warts, each with a black hair springing from the top. Illustrations of the moth and larva will be found on p. 112. Of other forms, the dromedary prominent (*Notodonta dromedarius*), the zigzag (*N. ziczac*), the



PUSS-MOTH (1) WITH CATERPILLAR (2) in two stages of development, and (3) COCOON ; (4) CATERPILLAR OF THE LOBSTER-MOTH.

kitten-moth (*Cerura bifida*), and the swallow prominent (*Pheosia dictea*), are amongst the more remarkable of the *Notodontidæ* indigenous to England. But we must leave this interesting group, and passing over the family *Cymatophoridæ*, including the peach-blossom (*Thyatira batis*), frosted green (*Polyphloca ridens*), buff-arches (*Habrosyne derasa*), and others, we reach

THE CLEAR-WINGS,—Family *SESIIDÆ*.

These elegant insects—whose transparent wings, attenuated bodies banded with yellow and red, dilate and hooked antennæ, give them no small resemblance to members of the Hymenoptera—are diurnal in their habits, flying swiftly to and fro in the bright sunshine. The larvæ are what is called internal feeders, burrowing in the trunks of various trees, or in the pith of shrubs. The pupæ are armed with little hooks, which enable them to move up and down their tunnelled galleries. There are many species even in England, one of the largest being the hornet clear-wing; and so closely do this moth (*Trochilium apiforme*) and its near relative (*T. bembiciforme*) resemble the common hornet, or perhaps more nearly the female of one of the smaller wasps, that only a practised naturalist would be

able to tell the difference, and then only on a close examination. The wings are transparent, and the body is black, striped and spotted with yellow. The moth has a curious habit, which increases the deception, and renders its likeness to some hostile wasp still more striking. If surprised sitting in the sunshine upon a poplar trunk, the abdomen will be arched upwards, and the tail tapped against the bark with a veritable—to all appearances—stinging movement. The larva burrows in



(1) HORNET CLEAR-WING, WITH LARVA AND PUPA; (2) GOAT-MOTH, WITH LARVA AND PUPA. (All nat. size.)

the wood of the poplar, and the pupa-skin may be found half out of one of the galleries when the moth has emerged. The insect is common all through Europe and Northern and Western Asia.

Family *Syntomidæ*.

The next family, the *Tiniageriidæ*, must be passed over, and a brief reference made to the moths of the family *Syntomidæ*, which introduces us to the well-known burnets. The *Syntomidæ* include small moths with broad, triangular, spotted wings, and body extended beyond the hind-wings. The members of this family are very similar in general appearance to the burnets, but differ in the absence of the ocelli. They are widely extended, and take the place of the burnets in the tropics of the Eastern Hemisphere. Among them, the spangled white (*Syntomis phegea*) is a common moth in some localities on the continent of Europe, with blue-black wings spotted with white, as represented in the illustration on p. 111. The larva is black, thickly clothed with hair, and feeds on the dandelion, while the perfect insect flies, somewhat like the burnets, in the sunshine, and settles upon flower-heads. It is not found in England, though extending through Europe to Northern and Western Asia.

We may also notice the handmaid moth (*Naclia ancilla*), a very rare species in England, but not uncommon in the woods of Southern and Central Europe in June and July. Its larva is black, with yellow lines on the back and sides, and it feeds on tree and rock lichens in spring.

THE BURNETS,—Family *ZYGÆNIDÆ*.

The burnets are for the most part small moths, with long, rather narrow fore-wings, and stout bodies extending beyond the hind-wings. Their usual colour is black, green, or dark blue, spotted with red, white, or yellow. The hind-wings are grey, red, or similar in colour to the fore-wings, with a narrow black margin; and the antennæ are somewhat abruptly narrowed towards the extremity. The burnets are local, though, from their gregarious habits, abundant where they occur. The larvæ are rather compressed, tapering at both ends; and the cocoon is long, spindle-shaped, yellow or white, of fine shiny silk, and attached longitudinally to grass-stems. Of the six-spotted burnet (*Zygæna filipendulæ*) the caterpillar feeds late in the autumn, and hibernates until the following spring. It is short, stout, slightly hairy, dull yellow, with two rows of black spots along the back, and feeds on grasses of various kinds. The moth flies heavily in broad daylight, and may often be seen, two or three together, hanging upon flower-heads in chalk-pits and on downs by the sea. Its fore-wings are black, with metallic green lustre, having six bright red spots placed in three pairs; and the hind-wings are bright crimson, with a narrow black border. The species, which is abundant in certain parts of England, as well as on the Continent, is shown in various stages of development in the illustration on p. 111.

THE CASE-WEAVERS,—Family *PSYCHIDÆ*.

An interesting group of moths, although not noticeable either for size or coloration, is that of the case-weavers. Their chief claim to notice is from the curious habits of the larvæ, which form from vegetable débris, twigs, chips, etc., a case in which they dwell, protruding merely the thoracic segments, with the three pairs of legs belonging to them. Some other moths, as for instance the genus *Coleophora*, also construct a tough case of a somewhat similar nature but manufactured entirely of silk. Amongst other insects the same habit of the larvæ is found amongst the caddis-flies, which creep on river-beds protected by a case of encrusted shells, pebbles, twigs, etc. In the moths of the present family the males alone possess well-developed wings, the females being wormlike, and often without antennæ, legs, or wings. The phenomenon known as parthenogenesis has been observed amongst members of this family. The moths are mostly dull brown insects, and the various species are better distinguished by a comparison of the larval-cases than of the insects themselves. Of the many species embraced in this family, one only can be described, and this but briefly. This species (*Psyche unicolor*) is a dull-brown little moth, common in Central and Eastern Europe, but



PSYCHE MOTH.

a, Male; *b*, Female, larva in case; *c*, Female pupa; *d*, Female moth; *e*, Male, larva in case; *f*, Male pupa. (All of nat. size.)

not found in England. The larva of the male moth makes a larger and more conspicuous case, than does the grub which will produce the wingless female. The larvæ hibernate securely enclosed in their cases, which are spun on a tree-trunk or other convenient object. In the spring the silken attachments are severed, and the larva continues to feed until the time of pupation has arrived, when it again spins up the mouth of the case to a tree or post, and changes within it to the pupa. The male then emerges as a perfect moth, but the female, which is devoid of eyes, ovipositor, or any appendages worthy of being styled antennæ or legs, remains in the larval-case even after it has emerged from the pupa. The organs for the production of eggs are, however, complete, and parthenogenesis must, as in many other cases, be looked upon as exceptional.

Family *COSSIDÆ.*

The moths belonging to this family, like those of several others, do not possess any proboscis; the antennæ being pectinate in both sexes. The larvæ are smooth, and feed sometimes for several years before pupating in the centre of tree-trunks of various kinds; a cocoon being formed of chips of wood within which the pupa awaits its final development. The family is typified by the goat-moth (*Cossus ligniperda*), in which the front-wings are of a rich brown, streaked and mottled with darker tints, while the hind-pair are dull brown. The larva—often known as the auger-worm—is exceedingly destructive to forest trees, the holes which it bores in its ravages being often half an inch, and even more, across. Its odour recalls that of a goat, hence the name given to the moth. A large, long, flat, broad larva, flesh-coloured, with short hairs scattered over the body, it is seldom met with, though it sometimes may be found as it crosses a road or footpath when seeking for a suitable place in which to spin its cocoon. It lives for over three years in the larval state, and makes a very tough cocoon from wood chips, glued together with a gum which it secretes. It is a native of Europe and Western Asia, generally appearing in June and July. It is figured on p. 101.

ALLIED FAMILIES.

The next family (*Arbelidæ*) must be dismissed without further remark. The *Hepialidæ* include the insects known as ghost-moths, one of which, the largest British species (*Hepialus lupulinus*) has the wings white above and brown below, so that when it flies in the dusk of the evening it appears and disappears in rapid sequence owing to the practical invisibility of the dull colour of the under side, in sharp contrast to the vivid white of the upper side. A near ally of the ghost-moth, likewise referable to the family *Hepialidæ*, is the splendid giant-swift moth (*Zelotypia stacyi*) of Australia, which has been selected for illustration in our coloured Plate, as being one of the finest of all moths. As the coloration and characters of this magnificent insect are sufficiently indicated in the illustration, it will only be necessary to give some account of its habits. Originally described from imperfect specimens found at the Manning River and in the neighbourhood of Newcastle, this moth was subsequently obtained in some numbers by the miners of the latter district. Mr. A. S. Oliff writes that "as the insect is rarely found in

the perfect, or imago condition, the larva has to be sought for and reared,—a matter of no little difficulty, as it lives, like those of the allied genus *Charagia*, in cylindrical burrows, which it makes in the interior of the stems or branches of trees, sometimes near the surface of the ground, and sometimes at a height of fifty or a hundred feet. By searching for these burrows, and rearing the larvæ, or pupæ, when found, a considerable number of specimens have been obtained by the miners; but I am informed that the supply is by no means equal to the demand."

The caterpillar is long, cylindrical, and fleshy. Above its general colour is pale yellow, with the divisions between the segments inclining to reddish brown. The first three segments are rather bright red; and the following segments, with the exception of the two last, are marked with three pale spots in the middle, and two on each side. The finely rugose head is black, as are the claws of the short legs. In the long and cylindrical pupa each of the abdominal segments beyond the extremities of the wing-covers is provided with a transverse serrated horny ridge near the front margin; the seventh to the tenth segments bearing similar but less prominent ridges; while the hinder extremity is armed with small sharp spines.

Usually the caterpillar makes its burrows in the wood of the grey gum tree; but there is some doubt as to whether it does not occasionally resort to another species of gum. Regarding the habits of the larva and pupa, Mr. Froggart writes that the former "changes into the chrysalis in December, after having eaten off the web in front of the bore, and placed a thick felty wad, or button, just inside the opening of the bore; but as soon as the chrysalis skin has become hard and firm, it pushes the wad away, and moves freely up and down the bore, which varies in depth from ten to twelve inches. It can move up and down the passage very rapidly, the curious file-like rings on the lower edge of the abdominal segments being evidently adapted to helping its locomotion. When nearly mature it has the habit, particularly in the afternoons, of resting in the bore, with the top of its head just level with the floor of the cross-bore, and plainly visible from the outside. The moths appear early in March. It has been found that they never come out after three o'clock in the afternoon; and chrysalids under observation, if not out at that hour, can be safely left until the next day." The next family (*Callidulidæ*) must also be omitted; while the *Drepanulidæ* may be referred to as containing the British species *Cilix spinula*, and the common hooktip (*Drepana falcataria*), and allied forms. Of the *Thyrididæ* there is but one European genus (*Thyris*) and no British species of this; while the next family (the *Limacodidæ*) is not of sufficient importance to detain us.

Family *LASIOCAMPIDÆ*.

The lappets, drinkers, and eggars, are well-known species included in this large family. These moths are large, for the most part, 2 inches to 2½ across the expanded fore-wings, others being smaller, about 1 inch only in expanse of wing, with stout hairy bodies and strong wings. They fly rapidly in broad daylight or at night. The larvæ are clothed with soft hair, that on the sides being often directed downwards in a tufted form. To the genus *Gastropacha* belong the lappet (*G. quercifolia*) and the oak-eggar (*G. quercus*); the common drinker pertaining to another genus (*Odonestis*), with the specific name *potatoria*. As examples

of the former genus we select for description the pine-lappet and the procession-moth, both abundant on the Continent, but not occurring in England. The larvæ of both these moths spin silken cocoons. Having the front-wings grey, tinted with different shades of brown, the pine-lappet (*Gastropacha pini*) is a large moth

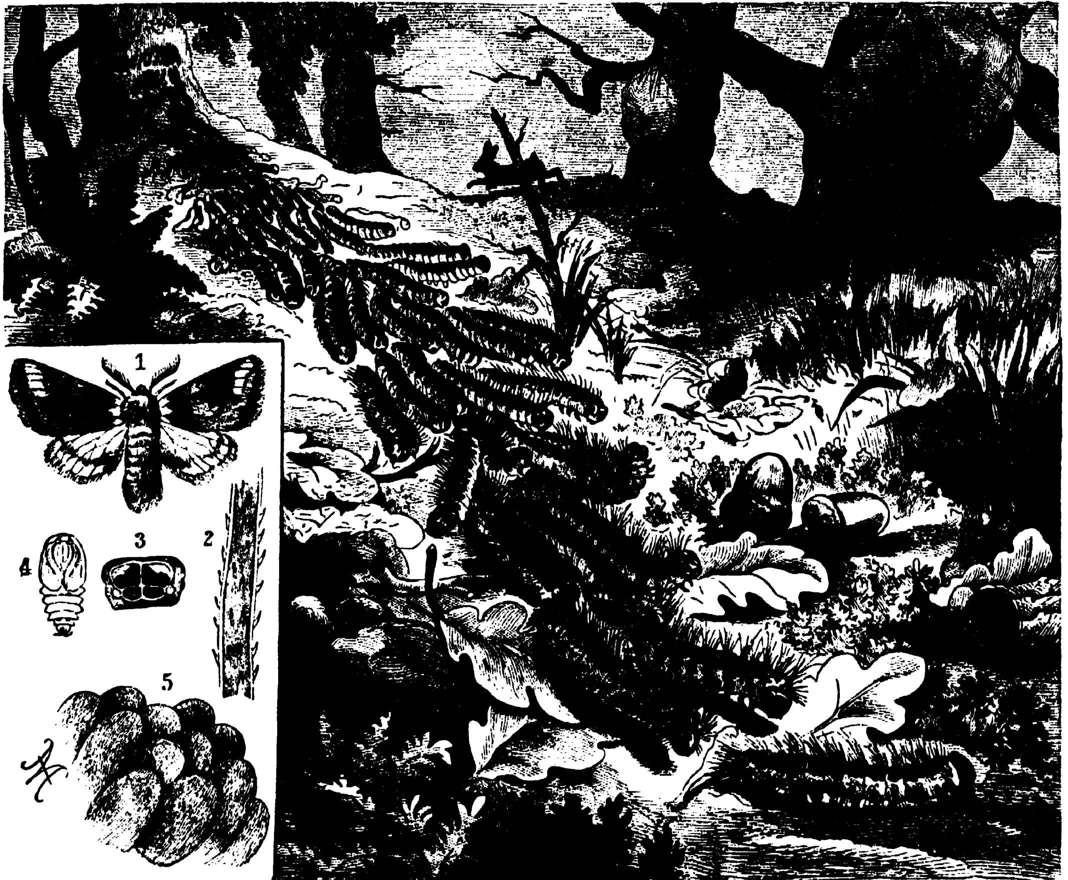


LIFE-HISTORY OF PINE-LAPPET MOTH.

a, Male; *b*, Female; *c*, Eggs; *d*, Larva; *e*, Cocoon; *f*, A beetle (*Calosoma*) attacking larva; *g*, Larva of *Calosoma*; *h*, An ichneumon laying its eggs in the pupa; *i*, Small parasites emerging from their cocoons on the remains of the larva which they have devoured.

measuring from 2½ inches across the wings. The larvæ are ashen grey, with a dorsal row of dark blotches, a lateral brown stripe, and a pair of blue transverse bands on the third and fourth segments. This handsome larva is often very destructive

to the pine-forests, where it feeds upon the needles of the trees, and sometimes appears in overwhelming numbers. In coping with the enormous quantity of caterpillars of this moth which devastate the district on these occasions, man is materially assisted by other creatures. Thus, a tree-frog ascends and feeds upon the larvæ; ichneumons of different species sting, and thus destroy, thousands; an internal fungus establishes itself in the caterpillar, with the same result; and, lastly, a beetle and its larvæ, which are represented in the illustration, render no small assistance in clearing off the pest. The caterpillars are hatched in the autumn and hibernate, remaining throughout the winter in the moss at the foot of the trees.



PROCESSION-MOTH (*Gastropacha processionea*). 1, Male; 2, Single hair of the larva; 3, Segment of larva; 4, The pupa; 5, The cocoons of several larvæ spun up together. (Nos. 2 and 3 enlarged.) The main illustration represents the migration of the larvæ in orderly procession.

In this state, coiled round in a spiral form, they may be frozen quite stiff, yet on the return of spring they regain vitality, and climb the trees in search of their usual provender. The red-brown cocoon is spun sometimes between the needles of the tree, as represented in the illustration, or else beneath some semi-detached piece of bark. In the procession-moth (*Gastropacha processionea*) the fore-wings are yellow-grey, with a glossy sheen, and dark indistinct oblique transverse bars. The larvæ are hairy with a blue-black back, pale sides, and red or grey warts on each segment. At night the caterpillars march out to feed in a regular orderly

procession, as represented in the illustration. One, the leader, marches at the head, followed by two, three, and so on, forming a wedge-shaped column. They ascend the oak-trees and return again in the same manner to their resting-place. They also spin their cocoons together as in Fig. 5 of the illustration. The species is common throughout Central and Southern Europe in August and September. As our last representative of the family we take the lackey-moth (*Clisiocampa neustria*), which is common in England and all through Europe and North and Western Asia during July and August. The fore-wings are dull ochre-brown, with two oblique transverse brown bars. The eggs are laid by the female in the late summer in a firmly attached ring round some small twigs, as shown in the illustration. The larvæ hatch in the spring following, and are brown with blue, white, red, and yellow longitudinal stripes; all feed on the leaves of the pear and other fruit trees, and spin a long sulphurous yellow cocoon amongst the leaves.



LACKEY-MOTH.
Perfect insect, eggs, larvæ, and cocoon.

Family *LYMANTRIIDÆ*.

This group includes a number of moths in which the males have the antennæ strongly pectinated, while in the case of the genus *Orgyia* the female is wingless. None possess a proboscis. The larvæ are hairy, and clothed with long thick tufts, springing in some places from wart-like prominences. The hairs of the larvæ are woven into the cocoon, and if they come in contact with the skin cause great irritation. In this family are included some well-known British moths, such as the vapourer (*Orgyia antiqua*), the pale tussock (*Dasychira pudibunda*), the black arches (*Lymantria monacha*), the gold-tail and brown-tail, the satin-moth, and many others. In the gipsy-moth (*Ocneria dispar*) the wings of the male are smoky black, while those of the female are grey; the appearance of the two sexes being very different indeed. The larvæ feed on various trees, and though very rare in England are sometimes so abundant on the Continent as to prove very destructive to all kinds of trees and herbage; stripping even maize and millet-fields, orchard, and vegetable produce.



HERMAPHRODITE GIPSY-MOTH.

The cocoon is formed in a few folded leaves spun together with silk or in a crevice in the bark. The single figure represents an hermaphrodite specimen

DEVELOPMENT OF GIPSY-MOTH.

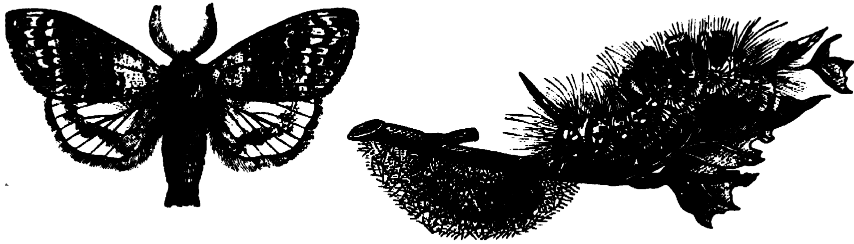
1, Male; 2, Female; 3, Pupa; 4, Larvæ in different stages. (Nat. size.)



BLACK-ARCHES MOTH.

1 and 2, Males; 3, 4 and 5, Females; 6, Young larvæ; 7, Full-grown larvæ; 8, Pupa. (Nat. size.)

of this insect. Its wings, antennæ, and the dark half of the thorax and abdomen on the left side are of the colouring and form peculiar to the male, while those on the right resemble the form peculiar to the female. The illustration on p. 108 illustrates the stages in the development of the black-arches moth,



PALE TUSSOCK MOTH, WITH ITS CATERPILLAR AND PUPA (nat. size).

which is not altogether abundant in England but much more commonly met with on the Continent. Indeed, so abundant is it at times that it causes great injury to forest trees. In Prussia, Lithuania, and Poland, the havoc has

BROWN-TAIL MOTH. 1, Male; 2, Female laying eggs; 3, Larvæ; 4, Pupa; 5, Antennæ of male; 6, Wing-scales; 7, GOLD-TAIL MOTH (*Porthesia auriflua*) larvæ; 8, Separate plumose hairs; 9, Segments of larvæ. (5, 6, 8, 9, enlarged.)

been particularly severe. In 1863 the moth appeared in countless thousands, driven up as a regular insect storm by the south wind. Within a few hours the moths spread over the whole country side, buildings were completely covered

by them, and the very surf of the lake assumed a more snowy whiteness, due to the colour of the hosts of moths drowned in the waters. The woods seemed as though visited by a violent snowstorm, so thickly were the insects massed in the foliage. In 1852 whole forests were felled, in order if possible to be rid of the pest. The trunks were searched for eggs, and every tree-trunk in an area of fourteen thousand acres was examined. Often an ounce of eggs would be taken from a single tree, and, at the computation of thirty thousand to the ounce, we get, at one hundred trees per acre, upwards of thirty hundred million larvæ at work upon the trees in that area when the eggs hatched. Spotted woodpeckers, finches of all kinds, the larva of a longicorn beetle, *Clerus*, all assisted in the work of destruction. Yet, in spite of all this, it needed a hundred labourers with twenty foremen to carry out the destruction of the young larvæ hatched from eggs which were overlooked in a single acre of forest. The ground too, after the season was over, was white with the cocoons of countless thousands of *Ichneumonidæ*, so that millions of the larvæ can never, from the attacks of these alone, have reached maturity. The pale tussock-moth (*Dasychira pudibunda*) derives its trivial name from the tufts or tussocks of hair so noticeable a feature in the hairy clothing of the larvæ. The fore-wings are grey with a smoky transverse bar. The larva is green with a transverse bar of velvet black between the segments from five to eight. Each of these segments bears a thick squarely truncated tuft of upright yellow hairs, and the last carries a long tail or brush of hair. The species is abundant in England and all Europe. In the brown-tail moth (*Porthesia chrysorrhœa*) the wings are snowy white, while the body is white with a brown tufted tail in the male, which in the female is much larger. The hairs of the tuft are deposited upon the eggs as a covering when laid by the female. The larva is short, thick, and black, with four rows of spiny tubercles along the sides. It is common in Great Britain and also on the Continent. Very similar to the last is the gold-tail (*Porthesia auriflua*), but the front-wings are dotted with three or more black spots, while the tuft at the extremity of the abdomen is formed of golden hairs instead of brown. The larva has rows of tubercles along the sides, whence issue numerous hair-like bristles. Each of the tubercles of the second row bears tufts of white hair. The third row is bright red. A bright vermilion double stripe runs along the back, while between the tenth and eleventh segments is a cup-like scarlet protuberance. The satin-moth (*Porthesia salicis*) is another well-known member of the family, taking its name from the white satiny wings; the antennæ and thorax being also white, and the body black, clothed with white hairs. The larva feeds on the poplar, and is abundant in England and throughout Europe.



SATIN MOTH (*Porthesia salicis*), WITH LARVÆ AND PUPA.
An ichneumon is depositing its eggs in one of the larvæ, while another is just emerging from the pupa.

THE TIGER-MOTHS,—Family *ARCTIIDÆ.*

Two families, including many tropical species, come between the *Lymantriidæ* and the *Arctiidæ*, namely, the *Pterothysanidæ* and the *Hypsidæ*. The forms included under the name *Arctiidæ*, embracing a number of beautiful moths, such as the tigers, ermines, etc., are usually divided into four subfamilies, the *Arctiinæ*, represented by the tigers, properly so called, the *Lithosiinæ* including the footmen, the *Nolinæ*, and the *Nycteolinæ*. Of the first subfamily, the most familiar member is the common tiger-moth (*Arctia caja*), which in summer comes freely to light. The fore-wings are rich chocolate-brown with cream-coloured markings; and the hind-wings crimson with black blotches. Two very beautiful



1, COMMON TIGER-MOTH; 2 and 3, Varieties of same; 4, Larva of same; 5, SIX-SPOT BURNET; 6, Its larva; 7, THE SPANGLED WHITE. (Nat. size.)

varieties of this exceedingly variable moth are figured in the accompanying illustration. The larva is the well-known woolly bear, a large swiftly moving caterpillar, clothed with long bristling black hairs, red at their base, which spins a loose web, thickly covered with the hairs with which it is clothed, and turns to a naked pupa.

THE OWL-MOTHS,—Family *NOCTUIDÆ.*

Passing over the family *Agaristidæ*, we reach the true night-flying moths, now included in the family *Noctuidæ*. This enormous group has been subdivided into no less than ten subfamilies. Of the first subfamily (*Trifeinæ*) the rustic shoulder-knot (*Hadena basilinea*) is a well-known example. In this moth the fore-wings are grey-brown, with a central transverse darker band, and a distinct dark streak at the base of the wing. The larva is grey-brown, with three white lines along the back. It feeds on various kinds of grass, and often on the ears of

wheat devouring the corn grains. As its scientific name implies, the pine-moth (*Trachea piniperda*) is in the larval state very destructive to pine-trees in seasons favourable to a great increase in their number. When young, they spin together the needles of the pines, and often drop themselves by a thread to various points, whither they may feel inclined to descend. The pupa may be found in plenty amongst the moss which so often carpets the ground in pine-woods. The moth itself is cinnamon-red, with white blotches and spots. It is common in England and on the Continent. A figure of the moth and larva is given on p. 105. The merveil du jour (*Dipthera orion*), figured in the illustration below, indicates another subfamily (*Acontinæ*). It has the fore-wings of a pale green, with longitudinal white stripes, and three broken transverse black bars, the fringe being spotted with black and white. The egg is described as resembling a sea-urchin, having twenty sinuous ribs. The larva is black, with large primrose yellow spots on the back of the third, fifth, and eighth segments. It feeds in



1, MERVEIL DU JOUR, WITH LARVA; 2, RUSTIC SHOULDER-KNOT, WITH LARVA; 3, FIGURE-OF-EIGHT MOTH, WITH LARVA.

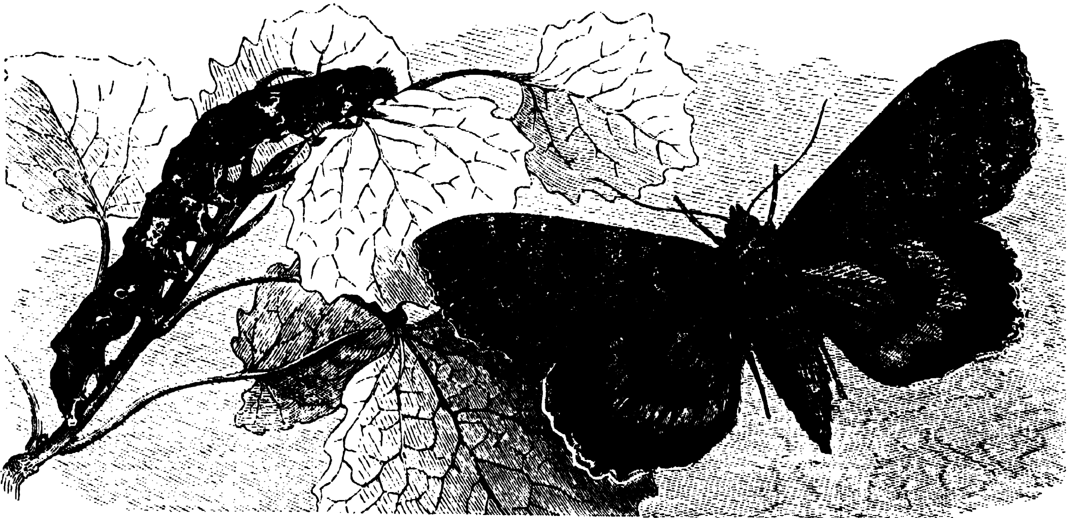
September upon the oak and birch, and the pupa is enclosed in a cocoon of bark chips, or fragments of decayed wood. This insect is very rare in England, but common on the Continent. In the same group, the caterpillar of the white-spotted pinion (*Cosmia diffinis*), as well as that of the closely-allied *C. trapezina*, are remarkable for their habit of preying upon their fellow-caterpillars if confined together, otherwise their food consists of the leaves of various trees. The moth of the species figured in the illustration is very beautiful, being of a satiny chestnut, suffused with reddish grey, and having two somewhat transverse slashes from the margin of the wing. Not uncommon in England, it is even more abundant on the Continent. The crimson under-wings (*Catocala*), which indicate another subfamily (*Guadrifinæ*), and are known in the New Forest as the crimsons, are rich chocolate-brown of various hues, with deep crimson under-wings, marked with a pair of transverse black bands. They come to sugar freely in July, and are common in some parts of England. The finest and rarest of these beautiful insects is the Clifden nonpareil (*Catocala fraxini*), very rare in England, but more

abundant on the Continent. Scarcely less striking is the red under-wing (*C. nupta*), in which the grey wings are mottled with darker shades, rendering it difficult to detect when resting on the grey bark of some forest-tree. The hind-wings are pale crimson, with a central curving transverse black bar, and another broad black band along the margin. The caterpillar is grey, with darker brown markings,



1, WHITE-SPOTTED PINION MOTH, WITH LARVA; 2, PINE MOTH, WITH LARVA. (Nat. size.)

bearing a pale yellow prominence on the ninth segment. It feeds on a species of willow, *Salix fragilis*, and the adult appears on the wing in August and September; being not uncommon in England, but found more abundantly on the Continent. In the angle-shades (*Brotolomia meticulosa*), which is one of the most beautiful, as it is one of the commonest of British moths, the larva is delicate green, smooth,



RED UNDER-WING, WITH LARVA (nat. size).

and velvety, thickly speckled with minute white spots. It feeds on groundsel. The perfect insect, which appears on the wing in May and June, and a second brood in September, is common throughout Europe. In the prettily-marked species known as the feathered gothic (*Neuronia popularis*) the fore-wings are dark brown, with white nervures. The orbicular and vermiform spots are of the

same colour. The antennæ are pectinate in the males, and simple in the female; while the hind-wings are dull white, with darker margin. The larva is brown, streaked and spotted with black and rosy brown, with a pale stripe along the sides, and four others, more interrupted, along the back. It feeds on the various kinds of grasses in April and May, while the perfect insect appears on the wing in the early part of September. Figures of this European species are given below. The next form for notice is the so-called antler-moth (*Charæas graminis*), which



1, THE FEATHERED GOTHIC, WITH LARVA; 2, ANGLE-SHADES; 3, THE ANTLER MOTH.

is probably one of the most destructive species in Britain, when, under the influence of a favourable season, the larvæ appear in very great numbers. The larvæ feed upon the roots of grasses, and it is no uncommon thing for whole districts of pasture-land to become brown and withered, owing to their attacks. The perfect insect appears on the wing in August and September. A figure of this moth is given above.

The Loopers,—Family *Geometridæ.*

The moths belonging to this group resemble in many respects the butterflies, having large, ample wings, a small head, and a narrow elongate body. The antennæ are not, however, clubbed; those of many of the males being pectinated. The palpi protrude only slightly, the proboscis is present in different degrees of development, while the head bears no ocelli on the top. When at rest, the majority of these moths carry their delicate wings slightly expanded, or closed over their bodies, like the roof of a house, sloping from the centre on either side. They are semi-nocturnal in their habits, appearing at dusk, and lying concealed during the day in bushes, trees, and herbage, whence they may be easily driven by beating the foliage. The larvæ differ very decidedly from those of the other families, several pairs of the pro-legs being wanting, so that locomotion is possible only by alternately advancing the front and hinder segments, the central portion of the body being thus raised in the form of a loop. The pupæ are sometimes, as in the butterflies, encircled with a silken thread, but the majority spin together a few leaves, and change within the receptacle thus formed, or burrow into the earth amongst dead leaves and moss. Of the first subfamily (*Boarmiinæ*) we select as a representative the handsome pepper-moth (*Biston betularia*), which is one of the largest of the European geometers, and resembles members of the family *Bombycidæ* in the possession of a stout abdomen. The form of the larva, however, is

quite distinct, and closely resembles that of a dead twig. Doubtless such a likeness saves it somewhat from the attacks of birds and ichneumon-wasps. When fully extended, and clinging only by its hindmost claspers, the caterpillar assimilates so marvellously with the brown and olive tints of the boughs among which it takes up its station, that it is almost indistinguishable from its surroundings. Another handsome member of the same group is the mottled umber (*Hibernia defoliaria*), which appears very late in the season, long after the majority of the members of the order have completed the term of their existence. By night the male circles around the trunks of trees in search of his wingless partner. In the former sex the large wings are pale ochre in colour, with a darker wavy transverse bar. The female, on the other hand, is variegated black and ochreous yellow, and bears no small resemblance to some species of spider. The larvæ feed on the buds of various trees, and descend into the earth to change into the pupa; the latter being dark mahogany, with a sharp spine at the tail. The species is not rare in England and on the Continent. The scarce umber (*H. aurantiaria*), which is figured in the same illustration, is less common than the last, but appears at the same season. Nearly allied is the winter-moth (*Cheimatobia brumata*), which in mode of life is somewhat similar to the mottled umber, but, as indicated by its scientific name, flies still later in the year. The larva lives partially secluded amongst the leaves which it draws together with silk. When occurring in great numbers, these caterpillars do serious damage to forest-trees and orchards. The male is of a dusky grey colour, with three darker bands across the upper-wings; while the female is wingless. In order to prevent the females from ascending the trees and laying their eggs on the foliage, it is the custom in Sweden to ring the trunk with a narrow band of some sticky substance. The bordered white (*Bupalus piniarius*) is another well-known member of the group. In this species the males are very abundant, flying amongst fir-plantations in England and on the Continent. The females are no less common, but do not take wing so readily. The larva is pale green, with whitish stripes, and pale yellow spiracles, and feeds during the months of August



PEPPER MOTH, WITH LARVA AND PUPA (nat. size).

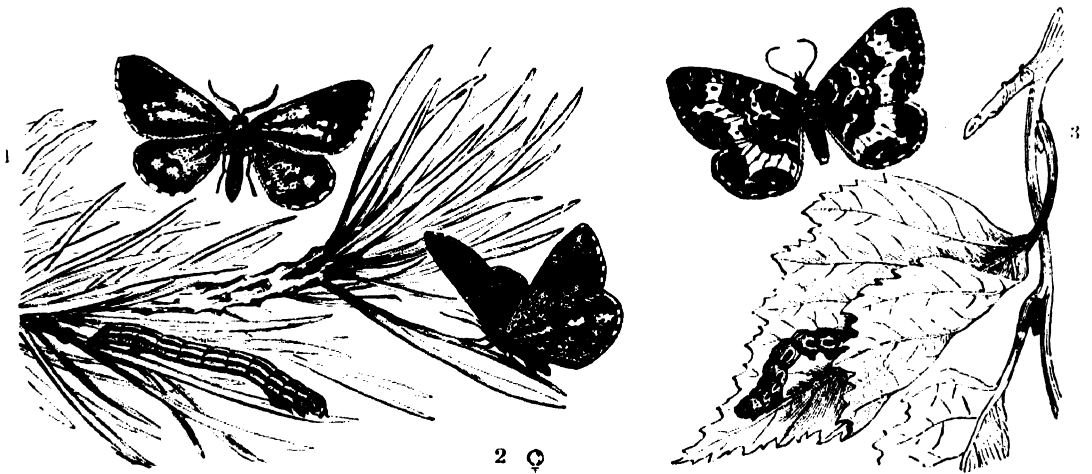
and September on the spines of the Scotch fir. One of the most familiar of the British loopers is the magpie-moth (*Abraxas grossulariata*), which at times makes



GROUP OF LOOPERS.

MOTTLED UMBER—1, Male; 2, Female; 3, Larva. SCARCE UMBER—4, Male; 5, Female. WINTER MOTH—6, Male; 7, Female; 8, Larva. (Nat. size.)

its appearance in great numbers. The perfect insect is prettily mottled with white and black, and on this account is called in Germany the harlequin-moth. Another species, the scarce or clouded magpie (*A. ulmata*), is more abundant in the Midland



BORDERED WHITE—1, Male; 2, Female, with larva; 3, ARGENT AND SABLE, with larva. (Nat. size.)

counties of England than the common magpie, though less so in the south. Of the common species the larva feeds on the gooseberry and black-currant, doing considerable damage at times. It is one of the most strikingly marked of the geometric

larvæ, and turns to a yellow-banded pupa within a slightly woven web. The little moth shown in the annexed illustration, and commonly known as the dark spinach (*Larentia chenopodiata*), may be taken to represent the subfamily *Larentiinæ*. Appearing in July and August, it is a common species on the Continent, and is specially abundant in gardens and shrubberies, where it may be found resting either on the bark of trees or the walls of buildings. The caterpillar is greyish brown in colour, and feeds on the goose-foot. The group to which this species belongs are often termed carpet-moths. Of another genus, known as pugs (*Eupithecia*), the lime-speck moth (*Eu. signata*) may be mentioned. The ground-colour of the wings is milk-white, with grey blotches and specks, and a broad red grey band on the margin. These moths fly commonly at night in England and on the Continent, while the larva, which is very variable in colour—bluish green, yellow-green, or pinkish white—feeds in August and September on various annuals, such as golden-rod, rag-wort, etc. Figures of the moth and larva are given in the illustration below. By no means a common species in England, although found occasionally in districts where birch-trees abound, the argent-and-sable (*Melanippe hastata*) appears in May, flying actively round trees. The larva may be found later in the year amongst the birch foliage, in a receptacle formed of several leaves drawn together with silken threads. The pupal-state is passed in the ground. Figures of this moth and its larva are given on p. 116. The purple-barred yellow (*Lythria purpuraria*), figured in the annexed illustration, is a not uncommon species on commons, pasture-lands, and stubble-fields in England and the Continent. The ground-colour of the wings is pale olive-yellow, the upper pair banded



MAGPIE MOTH IN ALL STAGES OF DEVELOPMENT.



DARK SPINACH MOTH AND LARVA (nat. size).



1, PURPLE-BARRED YELLOW; 2, LIME-SPECK. (Nat. size.)

with two or three pale vinous-purple bars. The larva, which is brownish yellow with a pale longitudinal dorsal stripe, feeds on sorrel and docks.

SNOUT-MOTHS,—Family *HYPENIDÆ.*

The snout-moths (*Hypena*) are intermediate between the *Geometridæ* and *Pyralidæ*, bearing characters which ally them to both families and yet exclude them from either. The common snout (*H. proboscidalis*) is a pale brownish yellow moth, transversely marked with rusty brown; and is abundant throughout England and the Continent from June to September. *H. obsitalis* has only once been taken in England.

Suborder **Microlepidoptera.**

The whole of the remaining members of the order are of minute size, and are hence generally indicated by the above name, although it must be understood that many of them are closely allied to some of the foregoing. They are divided into a large number of families—with their subfamilies and genera—of which only a very few can be even mentioned here. Among these the pearls (*Pyralidæ*) are represented by the mother-of-pearl moth (*Botys margaritalis*), which in June or July may be seen in Britain hovering over the fields in the dusk of the evening, where the female lays her eggs on the seed pods of the flax and other plants. When the caterpillar emerges it spins a few threads between the pods, and bores through their outer shell in order to feed upon the seeds. The moth itself is of a dull sulphur-yellow, with two transverse rusty yellow bands, intersected by a rusty brown stripe running obliquely from the tip of the wing. It is common in June and July on the Continent. To the same family belongs the meal-moth (*Asopia farinalis*), found in abundance in summer wherever corn, meal, or grains are stored in quantities. It rests on the rafters and walls in the daytime, flying at nightfall. The larva feeds on corn, meal, grain bran, etc., and passes its life in concealment in a silken tube, of which the outer side is encrusted with particles of the food-stuffs on which the larva feeds. The larval-state lasts for nearly two years. A figure of this species is given on p. 120.


MOTHER-OF-PEARL MOTH, WITH LARVA (nat. size).

The wax-moth (*Galleria mellonella*) may be taken to illustrate another family —the *Tortricidæ*. This remarkable moth is double-brooded, appearing on the wing in the springtime, and again in July and onwards. The larva feeds in the hives of honey-bees, and, according to some, in the nests of wild-bees as well. The wax, however—not the honey—forms its food-stuff, and through the combs it eats long tunnels which it lines with silk as it goes. It does not seem particularly choice in the matter of diet, and has been successfully reared on heather, woollen-stuffs, dry leaves, paper, etc. In the case of the wax-eaters, the

second brood nourishes itself upon the excrement of the first brood, which seems to differ in no way from the original wax itself. The moth appears on the wing in May. An illustration of this insect, together with the larva, pupæ, and the waxen honeycomb on which it feeds, may be seen on p. 121. Another member of the same family is the oak-tortrix (*Tortrix viridana*), figured in the annexed illustration. This beautiful little moth, bright green with shining grey hind-wings, may be found flying about in June in swarms in woods where oak-trees abound. The larvæ which feed on the leaves, and roll themselves carefully within the folded leaves, are sometimes so numerous as to become a perfect pest. Acres and acres of oak-plantation may be seen completely stripped of the foliage, while the green moths flutter about in countless thousands. The pupal-state is passed in a folded leaf or in the chinks of the bark or other suitable crevice. The larch-tortrix (*Retina buolinana*) is a bright, foxy red moth with habits very similar to those of the last-named species. The moth may be seen in July flying amongst the trees in young plantations, and laying



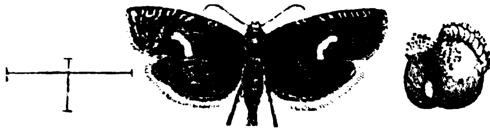
OAK-TORTRIX IN VARIOUS STAGES OF DEVELOPMENT (nat. size).



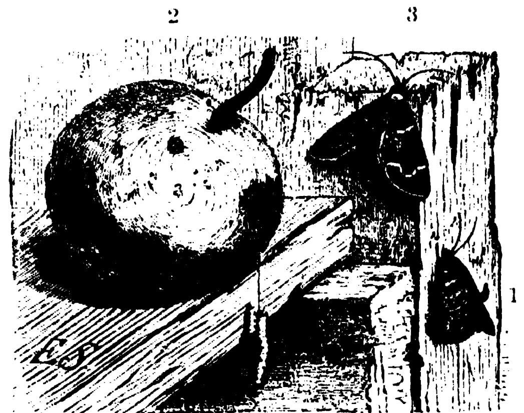
1, OAK-GALL TORTRIX; 2, Pupa appearing from the resin-gall; 3, *Glypta resinanæ*, ichneumon; 4, THE LARCH TORTRIX; 4*a*, Pupa; 5, Larva in a larch-bud; 6, Pupa appearing from gall. (1 and 4*a* much enlarged.)

its eggs amongst the buds at the tip of the shoots. The larvæ are hatched in the autumn, and commence to gnaw the buds, giving rise to the exudation of resin. A figure of this moth, with its larva and pupa, will be found in the illustration

on p. 119. In the allied pine-gall tortrix (*R. resinella*), the adult has dark fore-wings, streaked and mottled with transverse silvery bars and blotches. The larva feeds within the stem of the buds of the pine-needles, their ravages causing a drop of resin to exude from the twig which grows larger as the activities of the internal burrower increase. If the drop of resin be examined a small passage at the base will be found passing into the pith of the pine-twig, and here the larva may be found. This lump of sticky gum, which attains the size of a filbert, and in which the larva passes the pupal-state, has been misnamed a gall; but a gall is not an exuding juice or gum—it is a distinct outgrowth of the cellular structure of the plant. The woodcut on p. 119 gives illustrations of the moth, the resin-drop, and the pupa. A figure is also given of the ichneumon-fly, which seeks the larva with its long needle-like ovipositor; and from its eggs emerge the grubs which will in due course devour their nest. An especial interest attaches to the pea-moth (*Grapholitha dorsana*), whose larva is the so-called maggot which attacks green peas. When full fed it seeks the earth, and constructs a cell in which to pass the pupal-stage. These larvæ also are not averse to a provender of dry peas, to which it often causes considerable destruction. The moth appears on the wing in May. The well-known codlin-moth (*G. pomonella*) takes its name from the circumstance that the larva feeds within apple-trees, eating, however, not so much the flesh as boring into the heart and feasting upon the pips. It is rosy red, paler beneath, with grey tubercles, each bearing a long bristle. This moth flies in June and conceals itself in the daytime in a crevice in the bark, with whose tints its grey mottled wings readily assimilate. The family of the clothes-moths (*Tineidæ*) is typically represented by the lesser clothes-moth (*Tinea pellionella*), although it must be borne in mind that there is not one particular moth which destroys clothing, but that the larvæ of several species are equally destructive. *T. pellionella* is one of the smaller of these, whose larvæ, of a silky yellow colour, attack all kinds of clothing, as well as the upholstery of our furniture. *T. tapetzella*, a larger species, attacks more exclusively furs, skin-rugs, etc. A figure of the larvæ of one species will be found on p. 121. In the allied corn-moth (*T. granella*) the caterpillar is very destructive to corn in granaries, feeding indiscriminately upon various kinds of grain. The female lays one or two eggs on a single corn-grain; and after the deposition of all the eggs, the bodies of the adults may be found in numbers in spider-webs in places which they frequent. The presence of the

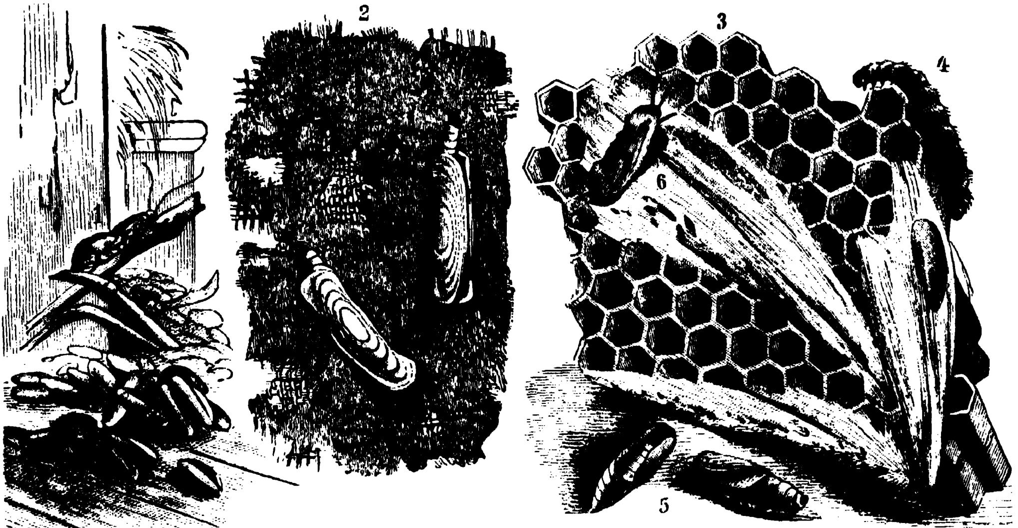


PEA-MOTH AND LARVA.



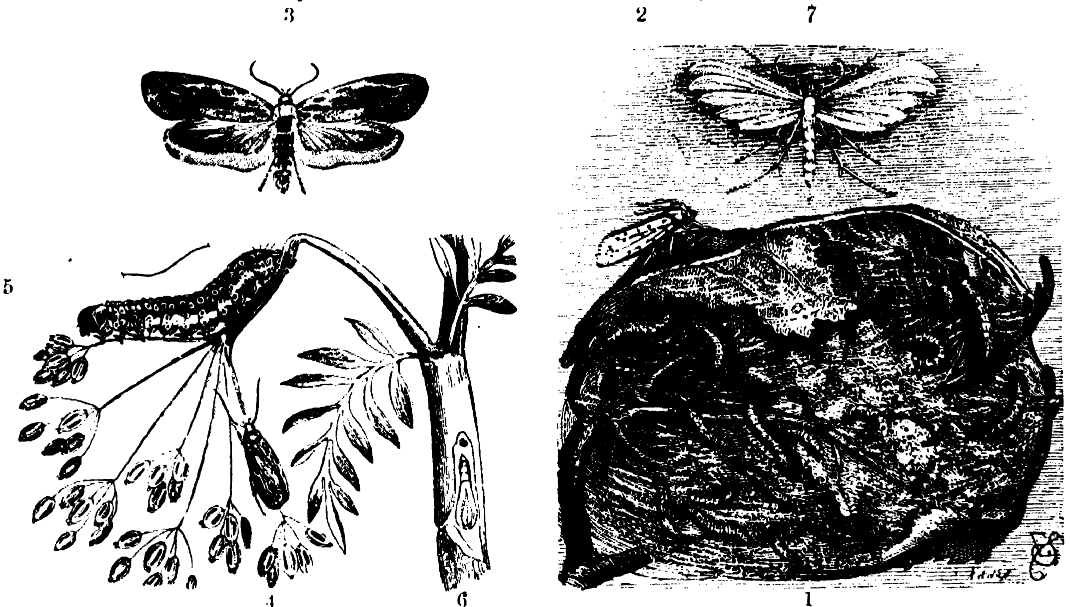
1, CODLIN-MOTH; 2, Its caterpillar; 3, MEAL-MOTH. (Nat. size.)

caterpillar may be known by the "pass" or excrement on the grains. Several grains may be spun together, the larva feeding within the shelter of the receptacle thus formed. Figures of both moth and larva are given in the accompanying



1, CORN MOTH, WITH LARVA. 2, LARVA OF CLOTHES MOTH. 3, HONEYCOMB, with 4, LARVA OF WAX MOTH; 5, Pupa; 6, WAX MOTH.

illustration. Of certain allied species there are no English names, so that they must be mentioned by their scientific titles. Among these, *Depressaria nervosa*,

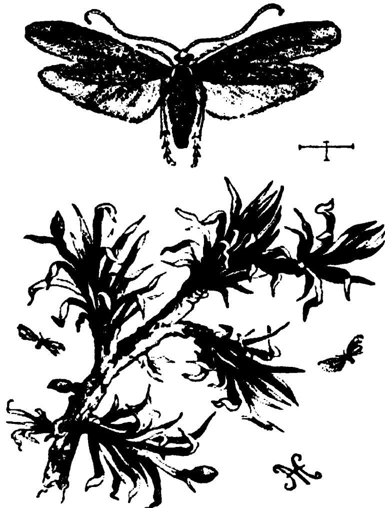


1, NEST WITH LARVÆ of *Hyponomeuta malinella*, and 2, The moth. 3, *Depressaria nervosa* (enlarged); 4, The moth (nat. size); 5, Larva (enlarged); 6, Pupa. 7, COMMON PLUME-MOTH (*Pterophorus pentadactylus*).

figured in the illustration above, appears on the wing from June to September, and has reddish grey fore-wings mottled and streaked with black dots. The female lays her eggs upon cumin, and the larvæ soon after they emerge spin together

the flower-heads, feeding on the seeds and blossoms. When about to enter the pupal state, the larva bores its way into the centre of the food-plant, gnaws out a suitable chamber, closes the entrance with a little door of silk, and remains safe from the attacks of insidious insect foes. In the same illustration is figured *Hyponomeuta malinella*, a familiar moth during June and July in English apple-orchards. The satiny white fore-wings, with three longitudinal rows of black dots, render it a beautiful and conspicuous object as it rests on the apple-tree by day, or flies to and fro beneath the trees as the evening draws on. The female lays her eggs in an elongated cluster on an apple-twig, and the presence of the larvæ first becomes apparent owing to the silky gauze net with which the tiny larvæ spin the leaves together, enlarging their domicile as occasion requires. When full fed, they pupate also in the web, so that numbers of tiny pupæ nestle side by side where the larvæ were wont to feed. When alarmed, the caterpillars drop to the ground suspended by a thread, crawling actively away amongst the grass.

Another family is typified by the genus *Coleophora*, which embraces about seventy species of small moths, characterised by their long narrow wings, margined with long delicate fringes, the first joint of the antennæ often bearing a tuft of hair. The larvæ live in little cases, in which they pass the winter, turning to the pupa in the spring. As an example of the genus, we figure the larch-mining moth (*C. larcinella*), which is a dull-coloured moth, whose larvæ eat their way into the needles at the tip of young larch-trees, the needles attacked, and indeed often the whole bunch, turning yellow and withering. The caterpillar is full fed towards the end of May, when it spins its little case fast to a larch-needle, and turns to a pupa within. A few weeks later the moth emerges at the hinder end of the case. Finally, we have the beautiful plume-moths (*Pterophoridæ*), of which the common species (*Pterophorus pentadactylus*) is figured in the illustration on p. 121. Throughout the family the larvæ are hairy, and when full fed suspend themselves by their anal claspers, turning to pupæ without any covering. The pupæ themselves are often hairy also, though many of them are quite smooth. The plume-moths, as a family, may be recognised by their feathery wings, slender bodies, and long spinous legs.


LARCH MINING-MOTH.

F. O. PICKARD-CAMBRIDGE.

CHAPTER IV.

Jointed Animals,—*continued.*

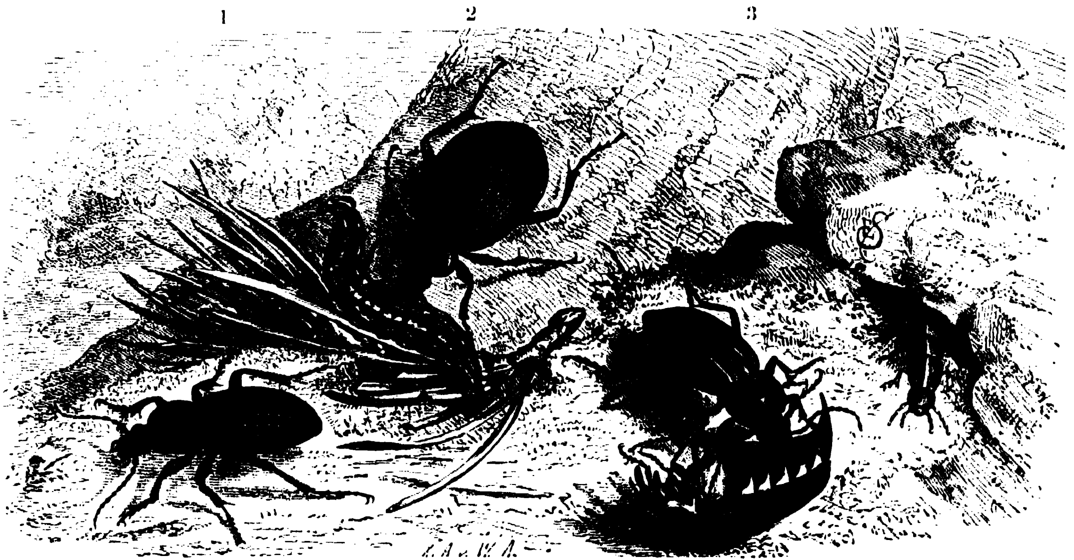
Insects,—*continued.*

The Beetles,—Order Coleoptera.

The beetles are in general easily distinguished from all other insects, and though they seem almost endless in their variety, and comprise an immense number of distinct specific forms, constitute a very well defined order. The chief characters that serve to distinguish them are briefly as follows. They undergo a complete metamorphosis. Their mouth—which is fitted for taking in solid food—is furnished with biting jaws (mandibles), a pair of maxillæ with palpi, and an undivided, or very slightly divided lower lip (labium), which also bears palpi. The antennæ are extremely variable in form, but seldom possess more than eleven joints. The prothorax is usually large and is freely articulated with the following segment (mesothorax), over which it fits behind in such a manner as almost to completely cover it on the upper side. The fore-wings are converted into a pair of stiff horny structures called elytra, which, in a state of rest, usually meet by their edges in a straight line along the middle of the back, and serve to protect the hind-wings and the soft hind-parts of the body. The hind-wings are in beetles the only true organs of flight; these are membranous and transparent, provided with few nervures, and when not in active use are generally folded transversely beneath the elytra. Many beetles are without hind-wings and are said to be apterous; but it is to be remembered that very few beetles, except in the larval state, are completely apterous in the sense of being without both hind-wings and elytra. In the wingless species the elytra are generally well developed, and frequently fastened together along the suture where they meet. The presence of elytra, though not exclusively peculiar to beetles, is still one of their most characteristic features, and affords in most cases a ready means of recognising them. Elytra very similar to those of some Coleoptera are, however, met with among the ear-wigs; and the elytra of beetles do not invariably meet in a straight suture. Thus in the oil-beetles (*Meloe*) one elytron folds partly over the other; while in certain other groups, the *Rhipiphoridæ* for example, the elytra are of such a form that they either do not meet at all, or only just touch at the base, and are sometimes so small and so little like the ordinary elytra of beetles that their true nature is not at first sight very apparent.

We have alluded above to the great variety that is to be met with among beetles. No insects exhibit greater extremes of size; and we find on the one hand beetles so small that a pin's head is large in comparison, while on the other

we get those giants of their race, the elephant and goliath beetles, which are nearly as big as a man's fist, and the still larger titan from South America, which is sometimes quite half a foot long, and scarcely less broad in proportion. Even within the limits of a single species beetles are not always of a nearly uniform size; and it is not uncommon to find that in certain species some individuals may be very much larger than others, frequently two or three times as large, and occasionally even as much as five times. In their external form beetles also afford the most striking contrasts; and the differences of form are not confined to the general shape but extend to nearly all parts of the body. The head especially varies to a great extent both in its shape and in the direction which it takes. It is somewhat ring-like behind, where it fits more or less deeply into the cavity of the prothorax. The part between the eyes and the prothorax may be as wide as or even wider than the rest of the head, or may be abruptly or



CARNIVOROUS BEETLES AND THEIR PREY.
1, *Carabus nemoralis*; 2, *Calosoma sycophanta*; 3, *Carabus auratus*, and larva. (All nat. size.)

gradually narrowed behind to form a sort of neck. In most beetles this part of the head is rather short, but its length varies: and there is one remarkable species from the Philippines which presents a most comical appearance owing to the extraordinary length of its neck. This species belongs to a group of leaf-rolling beetles, and doubtless finds its long neck extremely useful. The fore-part of the head is most variable in shape, and though generally short is in some beetles quite out of all proportion in its length. In the weevils it is prolonged in the form of a rostrum or snout, which is sometimes much longer than all the rest of the body. What is called the "front" of the head frequently faces upwards, being on the same plane, or nearly so with the occiput or posterior part of the upper surface. But in many beetles the fore-part of the head is bent down, so that the front looks forwards; and sometimes even to such an extent that the mouth is drawn back against the prothorax, and the front of the head looks downwards. The lower or anterior part of the front of the head is called the clypeus, and to this—usually by

the intervention of a short flexible piece known as the epistome—the upper lip (labrum) is attached. Running along the middle of the under side of the head there is a piece, generally marked off by a line on each side, which in its posterior part is named the gula, and in front the submentum. The submentum—sometimes prolonged beyond the margin of the head in the form of a peduncle—gives attachment to the lower lip (labium), which consists of a basal piece of variable size and form called the mentum, and a terminal part, the ligula. The latter usually bears two lobes (the paraglossæ) at its extremity, while from its base, known as the hypoglottis, the labial palpi arise. Between the labrum and labium lie the mandibles and maxillæ. The mandibles are strong biting jaws, and are attached to the sides of the head by pivot-like joints, which permit only of lateral movements. They are often much larger in the males than in the females, and in the males of some forms such as the stag-beetles, attain monstrous proportions. Each of the maxillæ consists typically of a stem, composed of two pieces—cardo and stipes—with a four-jointed palp attached to the outer and two lobes to the inner side of the free end of the stipes. Except in the larval state, beetles rarely possess those eyes with a single lens which are known as ocelli. The compound eyes, on the other hand, are generally large and well-developed, but vary considerably in form, and in the size and number of their facets. They are often simple in outline, sometimes slightly notched in front and reniform, or the notch may extend more deeply and divide the eye into two distinct lobes. Each eye may even be completely divided into two parts, more or less widely separated from one another; so that some beetles appear to have four eyes instead of two. This appearance is very strongly marked in certain water-beetles, in which one part of each eye is on the upper, and the other on the under side of the head. The eyes of some beetles look coarse and granular, while in others they appear quite smooth and glassy-looking, owing to the small size and slight convexity of their facets. Among the longicorn beetles, it is generally found that in the nocturnal species the eyes are coarser and more granular than in those species which fly during the day; so that the size of the facets seems to have some relation with the conditions of light depending on the habits of the insects. But this curious fact does not, so far as we know, apply to any other family of beetles. Exceptionally also it is found among beetles that the facets in the upper part of the eye are different in size to those on the lower part. The antennæ of beetles are scarcely less important in their functions than the eyes. They are in most cases sensitive to touch, and there is reason to believe that these organs are also the chief seat of the senses of smell and hearing. They appear under a variety of different forms, some of which, while subject to minor modification, are pretty constant throughout certain large groups of beetles, and thus account for the names, Clavicornia, Lamellicornia, etc., given these groups. As a rule the antennæ, no matter what their length, are made up of eleven joints or segments; but this number may be increased, in some cases to thirty or forty (*Rhipicera*), and even to as many as fifty (in the Longicorn genus *Polyarthron*), or it may be reduced even to so low a number as two (in *Platyrhopalus*). When the joints are more or less cylindrical in form, the antennæ may be either filiform, if of nearly uniform thickness throughout, setaceous if they taper towards the extremity, or moniliform if each of the joints is short and bead-like.

The antennæ are said to be clavate when thickened at the extremity, in the form of a knob or club; lamellate when three or more of the terminal joints spread out in broad processes which lie flat upon one another; serrate, when the joints have on one side short angular processes like the teeth of a saw; pectinate or comb-like, when the processes are fairly long and stand out nearly at right angles; or flabellate, if the processes are proportionately very long. These are some of the chief types of antennæ met with in the Coleoptera; others of less frequent occurrence will be mentioned when we come to treat of the different families. The sense of smell is undoubtedly very acute in a great many beetles, as anyone acquainted with their habits could easily testify; and it is considered probable that certain minute pits scattered over the surface of the antennæ, or crowded together on special areas, are in some way connected with this sense. Though it is not so easy to prove that beetles can hear, it seems hardly open to doubt that in some cases at least they possess this faculty. Every one has heard of the death-watch beetle (*Anobium*), which lives in old furniture and wood-work of houses, and makes a noise like the ticking of a watch. This little beetle produces the noise by hammering against the wood with its head, and apparently does so for the purpose of attracting its mate, who replies by making a similar tapping sound. It is easy by imitating their sounds to get the beetles to answer back; so that here at least there is some evidence that these insects are endowed with the faculty of hearing. Many other beetles are able to make sounds, which though not nearly so intense as the chirping of the crickets and grasshoppers, and not usually confined to one sex, are produced somewhat after the same manner by the friction of one part of the body over another. In beetles the sound sometimes arises from the rubbing of the hind-legs against the edge of the elytra, but in most cases it results from the rubbing of an edge over an adjacent area which is crossed like a file by a number of fine parallel ridges. This stridulating area is in some beetles placed on the upper side of the back part of the head, or on the gular surface underneath, so that when the head moves in its socket the upper or lower edge of the prothorax, as the case may be, scrapes along the file and thus gives rise to the sound. The prothorax of beetles is, as we have already stated, freely articulated with the mesothorax. Its dorsal arch or pronotum ordinarily covers over the whole of the mesonotum, with the exception of the small piece known as the scutellum; but when the prothorax is bent down, a considerable part of the mesonotum in front of the scutellum comes into view. It is on this part that the stridulating area of most of the longicorns and of some phytophagous beetles (*Megalopinæ*) is situated. These insects make a sort of squeaking noise—which is sometimes fairly loud—by rapidly bending the prothorax up and down, and so causing its hind edge to move backwards and forwards over the ribbed surface of the mesonotum. In other beetles the stridulating area may be either on the upper surface of one of the hinder segments of the abdomen, or on the sides of one of the anterior segments; the sound being produced in the one case by the friction of the area against the edge of the elytra, in the other by that of the posterior thighs against the sides of the abdomen.

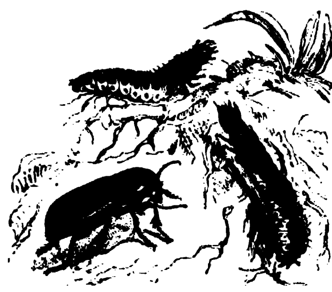
Beetles are among the most active of insects when on the ground, and, in accordance with their running powers, we find that their legs, though generally slender, are strong and well developed. But in certain groups, where the habits and environ-

ment of the insects require it, the legs are adapted to various other purposes. Beetles that jump usually owe their leaping powers to the greatly thickened femora and straight and relatively long tibiæ of the hind-legs. It would, however, be a mistake to suppose that when a beetle has thickened and strongly developed hind-legs it must consequently be able to jump. Some burrowing species, and others that are not very active in their movements, have very thick hind-legs; though, as a rule, it is the front pair of legs which is thickened and otherwise modified to serve as digging organs in those beetles that burrow underground. In aquatic beetles the swimming legs are disposed like oars, and have all their parts broad and flat, while their breadth is further increased by rows of bristles. Either the hind-legs only, which is the rule, or the middle pair also, as in the whirligig beetles (*Gyrinidæ*), may be thus transformed into swimming organs. The coxæ, or basal joints of the legs, vary much in shape and in the mode in which they are inserted in their sockets on the under side of the thorax. Those of each pair are sometimes close together, sometimes widely separated from another; while a longer or shorter distance may intervene between the coxæ of the different pairs of legs, and especially between those of the two hinder pairs. Considerable importance attaches to the number of joints in the tarsi or feet. In classifying beetles this number is one of the first things to be noticed. If a beetle has five joints in each of its tarsi, it is placed in that section of the order which is known as the Pentamera; if it appears to have only four joints in each foot, it belongs to the Tetramera; and if but three, to the Trimera. When there are five joints in each of the four anterior feet, and only four in the hind-feet, the beetle may be regarded as one of the Heteromera. To these general rules there are a few exceptions which need not be discussed here; but we must point out that although in the Tetramera the tarsi appear to be four-jointed, and in the Trimera three-jointed, they are really composed of five joints and four respectively. The fourth joint in the one case, and the third in the other, are, however, usually so small as not to be noticed except upon very close examination. The abdomen is never stalked in beetles, but attached to the thorax by a broad base, which is applied against the posterior coxæ; exceptionally, however, as in certain mimicking species, its base may be more or less narrowed. It is generally somewhat flattened in shape; and on the upper side eight segments are usually distinguishable, which, so far as protected by the elytra, have a soft and but slightly horny integument. Five or six segments are generally visible on the ventral side, but in certain cases the number may be reduced. The terminal segments are usually retracted within the abdomen, and completely hidden from view, but in the females of many species they can be exserted in the form of a tubular ovipositor, which enables the insect to lay its eggs deep in the crevices of bark.

Although beetles do not always exhibit differences in external form by which the sexes may be distinguished, such differences frequently exist, and are sometimes of the most pronounced character. As a rule, the male is more slenderly built than the female, and has longer and more fully developed antennæ; his eyes also are often larger, and in the length and shape of the legs, and in the width and structure of the tarsi, differences in the two sexes are frequently to be noticed. When the male is fully equipped for flying, the female may be without wings, or

even, as in the case of the glow-worm, without elytra; and whenever there is any decided difference in coloration, it is almost invariably the male which displays the brightest and most conspicuous colours. The great projecting horns and processes on the head or prothorax which give so grotesque an appearance to many beetles, are generally wanting or only feebly developed in, the females; and these and other differences are sometimes so strongly marked that it is difficult to recognise in the two sexes individuals of one and the same species.

The larvæ of beetles do not in outward appearance exhibit anything approaching the great diversity seen in the perfect insects. They seldom display conspicuous markings, and are mostly of dingy white, brownish, or black colours. The external structure and form vary sufficiently to make it possible to tell to what family of beetles, or division of a family, a larva belongs; but, so far as species are concerned, our knowledge of the larvæ is extremely limited, and applies to a relatively very small proportion of the whole number of known species of Coleoptera. In the weevils, and some other beetles, the larvæ are soft white grubs with scarcely any trace of legs, but in most of the other larvæ the legs are fairly well developed, though not so completely as in the perfect insects. The head is always horny, and furnished with jaws for biting and grinding solid food. Exceptionally, as in the carnivorous larvæ of some water-beetles, the mandibles are adapted for sucking up the juices of the animals on which these larvæ prey. The antennæ are short and few-jointed, and in some cases quite inconspicuous. Eyes, when present, are always in the form of ocelli, which are grouped together in varying number on each side of the head. The head is followed by a series of rings or segments, of which the first three—scarcely different in form from the rest—constitute the thorax, and give attachment to the legs. A pair of prolegs is sometimes present on the last segment, but in beetle-larvæ the intermediate segments never carry those false legs, which are so often found in the caterpillars of Lepidoptera and Hymenoptera. The spiracles—which are mostly hidden by the elytra in the perfect insects—are generally quite conspicuous in the larvæ, and appear as a row on each side of the body. Their number varies; and in those aquatic larvæ which breathe by means of tracheal gills they are altogether wanting. When about to pupate some larvæ construct cocoons of earth, or, in the case of wood-boring species, they may make a shell out of fine chips and dust glued together with a sticky secretion. The pupæ, whether enclosed in a cocoon or not, are inactive, and show all their appendages lying freely against the body, with each appendage wrapped round by its own special covering of integument. The larval existence of beetles varies from five or six weeks in some groups to almost as many years in others; and when conditions arise to interfere with the proper nourishment of the larvæ, the period may be unduly prolonged. Some of the wood-boring larvæ seem to live an exceptionally long time. There is at the present time in the Natural History Museum in London a block of wood containing a living longicorn larva, which for the past five or six years has been feeding and



Zabrus gibbus and its larva (nat. size).

burrowing in the wood. The larva was brought to the museum in a boot-tree, which its owner previously had in constant use for over fourteen years. Other cases are on record in which beetles have been seen to emerge from furniture in houses, after having apparently passed an even more prolonged larval existence.

Beetles, whether from the extent of their numbers or the variety of their shapes and instincts, are well qualified to play an important part in the economy of nature. Their chief function is that of universal scavengers. Not only do they dispose of the smaller quantities of dead and decaying animal and vegetable matter passed over by larger animals, but, by their own peculiar methods, they are enabled to attack and clear away even the carcases of quadrupeds of large size, and the dead trunks of the largest trees. Owing to the compactness of their shape, and the solidity of their outer covering, they are adapted for a much greater diversity in modes of life than is possible for insects of other orders. Besides groups fitted to act as scavengers, we find further series of forms that live in, and prey upon, all kinds of plant life. There are groups again, either of terrestrial, arboreal, or aquatic habits, which seek for, and prey upon living animals of the smaller kinds. Some beetles live within the depths of the darkest caverns; and in such cases, having no use for eyes, they are generally blind. Others are to be found dwelling as "guests" in the homes of the ants and termites. Although the beetles cannot boast of such a long line of ancestry as the cockroaches and other Orthoptera, yet their records go back to an early period in geological history. There is no certain evidence that they existed in Palæozoic times, and their first appearance has not been traced farther back than the beginning of the Secondary epoch. The earliest undoubted fossil remains of Coleoptera occur in the Swiss Trias, and from this period onwards fossil beetles are to be met with in greater or less abundance in rocks of different ages. They are especially well preserved in amber; and from the Tertiary amber beds on the Baltic thousands of specimens have been collected.

Of the beetles now existing, quite one hundred and thirty thousand different species have been described, and, considering the rate at which new species are being yearly added, it is probable that before the end of the century the number of named species will fall little short of one hundred and fifty thousand.

SECTION PENTAMERA.

Beetles in which all the tarsi are five-jointed. In this section there comes first a great tribe of beetles, which, on account of their carnivorous tastes and predaceous habits, are known as the Adephaga. Their whole organisation seems well adapted to enable them to capture and devour their prey, and it is in the modifications directed to this end that some of the chief distinguishing characters of the tribe are to be found. Their legs are fitted for speedy locomotion, and their jaws for the cutting and tearing operations to which they are usually applied. The mandibles are acutely pointed and have sharp cutting edges; and the inner lobes of the maxillæ are hard and hooked at the end. The outer lobes of the maxillæ are two-jointed and slender, and resemble palpi; which explains the fact that these beetles are often described as having three pairs of palpi. The antennæ are usually simple, and never clubbed. The tribe is divided into the Geodephaga and Hydradephaga, one subtribe containing terrestrial, the other aquatic forms.

The *Cicindelidæ* consist of about one thousand known species, which are distributed throughout the world, but are much more abundant in tropical than in temperate or cold countries. In Europe two genera only are represented—*Tetracha*, which comprises nocturnal and twilight-loving species, and *Cicindela*, whose species are found in the hottest and sunniest places. The tiger-beetles are extremely pretty insects of remarkably active habits, and exhibit the predaceous type of structure to perfection. Besides possessing great speed of foot, most of them make ready use of their wings, and they are further characterised by large and prominent eyes, and mouths well adapted for seizing and holding their prey, the mandibles being long and provided with a number of sharp teeth, while the inner lobe of the maxillæ is furnished with a movable claw or hook at the tip. The fact that this hook is movable and not firmly fixed to the blade of the maxillæ, affords a means of distinguishing the tiger-beetles from all the other beetles of the tribe Adephaga. More than half of all the known species of the family belong to the single genus *Cicindela*, and this is the only genus which is cosmopolitan. With the exception of a few species of an almost entirely ivory-white colour, the *Cicindelidæ* exhibit greenish, bronzy, or darker metallic tints, frequently varied with white or pale yellow spots and bands, which in the case of a great many species run together to form more or less intricate and pretty patterns. While their shape is usually such as is shown in our figure of *C. hybrida*, we get, on the other hand, remarkable exotic forms, in which the body is narrow and elongated, and broadest towards the hinder end. *Collyris* and other genera of the various Oriental countries—where the species are found pursuing their prey on the trees in the forests—afford examples of this type. From its great resemblance in colour and form to *Collyris*, a rare and curious longicorn beetle, found in the same localities, has been named *Collyrodes;* and it has been remarked by Mr. Wallace that beetles of the family *Cicindelidæ* are amongst those most frequently mimicked by other beetles.



TIGER-BEETLES.
Cicindela hybrida (with larva and pupa slightly enlarged); *Collyris longicollis* (enlarged).

In external structure the carnivorous ground-beetles (*Carabidæ*) approach the *Cicindelidæ*, from which they may in most cases be distinguished by their general shape, as well by the fact that they never exhibit the coloration and markings characteristic of that family. Other points of difference may be seen in their less prominent eyes, in the absence of an articulation in the hook of the maxillæ, and in the shape of the mandibles, which, though occasionally long,

do not exhibit the slender curved form and sharp dentition met with in the tiger-beetles.

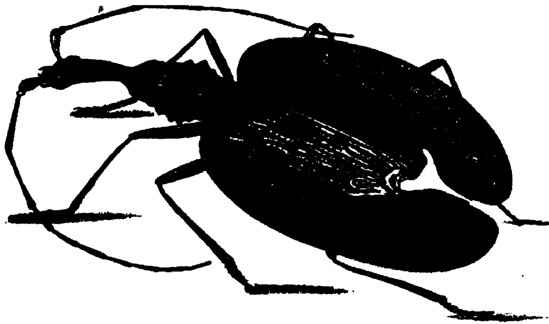
The number of species of *Carabidæ* at present known can scarcely be less than eleven thousand. This family seems better represented in temperate and colder regions than within the tropics, though species, in more or less abundance, are to be found in every country and island of the world. Whilst the species are almost all predaceous in their habits, we find them under a variety of different forms and with several distinct peculiarities of structure, many of which are to be regarded as special adaptations to the various situations in which the insects hunt for their prey.

The *Carabidæ* like all other beetles have their enemies, but we never find in this family any of those mimetic and protective disguises that are so commonly met with in certain other groups; and to escape from their enemies the ground-beetles have mostly to rely upon their speed of foot, or the readiness with which they can take to flight or disappear amongst the herbage. Many species are, however, provided with anal glands that secrete an acrid or stinking liquid which is sometimes ejected with considerable force when the insect is handled. In the "bombardier-beetle" (*Brachinus crepitans*) and others of the same group, the secretion is volatilised on emission, and issues as a little cloud of smoke, which is accompanied at each discharge by a slight sound; and when the insect is irritated it repeats the discharge several times in succession, but each time with diminished force. The "bombardier" is a rusty-red species, with dull blue-black elytra, and a narrow head and prothorax, and is pretty common, especially on chalk, in different parts of the south and south-east coasts of England. Amongst those species of the family that in habits and general appearance most closely resemble the *Cicindelidæ*, are the little beetles of the genus *Elaphrus*. These love to run about in the rays of the sun, not so much in dry places, as on the muddy banks of rivers, on the sands of the seashore, and in other damp situations. They have large prominent eyes, a narrow prothorax, slender legs, and curiously marked elytra. This genus is confined to the Northern Hemisphere. The species which we figure, *Elaphrus riparius*, like some other beetles of the family, is able to produce a stridulating noise by rubbing the back of its abdomen against a projecting nervure on the under side of the elytra. Those tiny little beetles of a glistening bronzy-black appearance, and with beautifully sculptured elytra, which are to be seen on almost any bright day in the spring or summer, running quickly over garden beds or paths, belong to the genus *Notiophilus*, and are some of the smallest species in the whole family. The genus *Carabus*, after which the family is named, contains over three hundred species, and is somewhat remarkable in its distribution; for, with the exception of a small group of species found in Southern Chili, it is restricted in its range to the North Temperate zone. Six or seven species are found in Britain; *Carabus violaceus* and *C. nemoralis* are perhaps the two most frequently met with, being abundant in gardens and fields in almost every part of the country. The first is nearly smooth, of a dull blue-black colour, with purplish borders to the thorax and elytra, and is of about the same size



Elaphrus riparius (enlarged).

as *C. nemoralis* (represented in the figure on p. 124). The latter has a purplish thorax and bronzy elytra, marked with a few rows of conspicuous punctures. Another species which we figure, *C. auratus*, is very rare in England and doubtfully indigenous, but in France it is common and does much service by destroying the cockchafers and their grubs. The genus *Calosoma* approaches *Carabus* in many of its characters, but may be easily distinguished by its shorter, broader, and more rounded prothorax, and the greater relative width of its elytra. *Calosoma inquisitor*, though rare and found only in parts of England, may be regarded as a true British species; but the species figured (*C. sycophanta*) is only an occasional visitant to this country and cannot be considered indigenous. The *Carabidæ* as a whole, though sufficiently varied in their external structure, do not exhibit any very unusual or striking peculiarities of form, and the species already considered, with a few more presently to follow, may be taken as typical of the commoner forms met with throughout the family. In the genus *Mormolyce* we have, however, a remarkable exception. The species of this strange genus—three in number, and all very much alike—have been found in Java, Sumatra, and other East Indian Islands. They are of a pitchy-brown colour, and have the body much flattened, and the head greatly elongated, while their antennæ are also very long; but, as will be seen from our figure, the chief peculiarity in the appearance of these extraordinary insects is due to the great lateral expansions of the borders of the elytra, and the curious manner in which these expansions are prolonged behind. *M. phyllodes*, the best known species, occurs in Java, Borneo, and the Malay peninsula; and the people of Java, struck no doubt by its peculiar shape, call it "the violin." Some of the largest individuals of the species are nearly three and a half inches long, and measure more than an inch and a half across the broadest part of the elytra. We have alluded, in our introduction, to the burrowing habits of some of the *Carabidæ*. The *Scaritinæ* are a group that possess such habits, and the accompanying figure of *Scarites gigas* will give an idea of the general form characteristic of nearly all the species of the group. The genus *Scarites* comprises a large number of species, all of a uniform black colour, and most of them of a moderate size. They make their burrows in the banks of streams, the seashore, or other suitable places, and rarely leave them during the day, lying in wait for their victims at the mouth of the holes. The genus *Zabrus*, which we have next to notice, forms, so far as its habits are concerned, one of those exceptions that go to prove the rule. For, while it is true that almost all the *Carabidæ* are carnivorous and predaceous insects, some at least of the species of *Zabrus* and a few others are largely, though probably not wholly, addicted to a vegetable diet. The species (*Zabrus gibbus*)


Mormolyce phyllodes (from a small specimen).


Scarites gigas (nat. size).

figured on p. 128 lives in corn-fields, and has at different times committed great havoc among crops—wheat, barley, rye, etc., in various parts of Germany and Italy.

The *Dytiscidæ* or carnivorous water-beetles, resemble the *Carabidæ* in many of their structural features, and differ chiefly in the modifications undergone to fit them to an aquatic mode of life. Thus we find, as in the latter family, the mentum is usually broad and deeply emarginate in front, the outer lobe of the maxillæ is two-jointed and palpiform, the antennæ are moderately long and slender, and the trochanters of the hind-legs are prominent. On the other hand, the antennæ are always smooth; the head is broad and fits deeply into the prothorax, while the latter is applied by a broad base against the elytra, so that the outline of the body is continuous, and the general shape more or less oval; the hind-legs,



Dytiscus marginalis — 1, Male; 2, Female; 3, Eggs; 4, Pupa; 5, Larva attacking a tadpole; 6, *Hydrocharis caraboides*; 7, Its larva; 8, *Acilius sulcatus*, Female. (All nat. size.)

which with their tibiæ and tarsi flattened and furnished with rows of bristles, are adapted to serve as oars in swimming, are somewhat longer than the other legs, and come off from the body at a considerable distance behind them, while their coxæ appear as broad flat plates firmly joined to the metasternum, for parts of which they might at first sight be very readily mistaken. The males may be distinguished from the females by the shape of their fore-tarsi, in which the first three joints are strongly dilated, and furnished underneath with sucker-like hairs; while in this sex also the back is generally smooth and glossy, the elytra of the females frequently have a ribbed or corrugated surface. The *Dytiscidæ* seem especially fond of stagnant waters, and some of the species are common objects in our ponds and ditches. They come to the surface when it is necessary to take in a fresh supply of air beneath the elytra. These organs fit very closely against the sides of the body, and so prevent the air from escaping while the beetle

is swimming about under the water; but the air meanwhile is being used up in breathing by means of the thoracic and abdominal spiracles. The beetles fly strongly, and on fine summer evenings may sometimes be seen winging their way to new quarters, a change which is often necessitated by the drying up of the pools in which they had previously been living. *Dytiscus marginalis*, one of the largest British species, is also one of the commonest and best known. Another common species, *Acilius sulcatus*, is also represented in our figure.

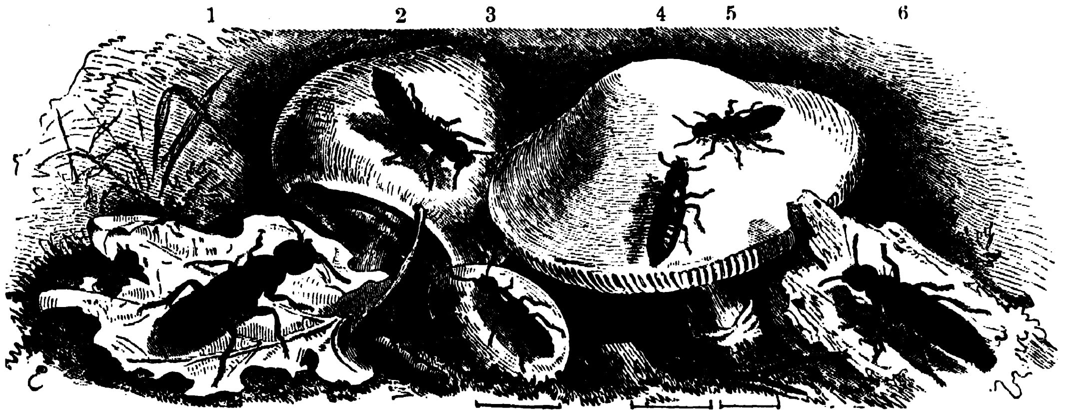
The *Gyrinidæ*, or whirligig beetles, are a small but very well-defined group, and in many points of structure are sharply distinguished from the other families of the tribe Adephaga. In their oval shapes they resemble the *Dytiscidæ*, though they are usually somewhat flatter below and a little more convex on the upper side. But in the relative proportions of the three pairs of legs they are entirely different. The fore-legs are long and slender, and when stretched out look like arms, whereas the two hinder pairs are short and broad, being modified for use as paddles in swimming. Another very distinctive feature is presented by the eyes, each of which is divided by a ridge on the side of the head into two widely separated portions, one lying on the upper side of the head and the other underneath. These beetles appear, in consequence, to have four eyes; one pair, as it is said, though there is no proof of the fact, for espying objects above them, the other for looking at things in the water below. From the *Dytiscidæ* and *Carabidæ* they differ further in having their antennæ shorter than the head, and the outer lobe of the maxillæ either completely atrophied or else in the form of a slender spine. The *Gyrinidæ*, though widely distributed and represented in almost all parts of the world, include altogether rather less than three hundred known species. The genera are few in number and two only occur in Europe. Some of the British species, such as *Gyrinus natator*, are commonly to be seen in ponds and canals or "holes" in reedy sluggish streams, where the shiny little beetles attract attention by the ease and rapidity of their movements as they skim about on the surface of the water, performing a variety of intricate evolutions, some sweeping along in graceful curves, others going round in circles or spiral tracks, now all collecting together in groups, and then, if startled, suddenly darting off with amazing speed in every direction.



COMMON WHIRLIGIG BEETLE, *Gyrinus natator* (enlarged).

The next beetles we have to consider are those which, on account of their abbreviated wing-cases, are known as the Brachyelytra. This tribe to which, however, not all beetles with short elytra belong, contains a single very large family—the *Staphylinidæ*. Owing to the shortness of their elytra, and the usually narrow and elongated form of their bodies, the rove-beetles have an easily recognised and characteristic appearance. The head is generally large and flat with a narrow neck behind where it fits into the prothorax. The antennæ—composed of eleven, or occasionally twelve joints—are usually filiform, but are often slightly thickened towards the extremity, and in some cases end in a distinct club. Though prominent and conspicuous in a few genera, the eyes are, as a rule, raised but very little above the general surface of the head. It is interesting to note that ocelli, which are of such rare occurrence in adult beetles, are to be found in certain groups of this

family; two ocelli being present in *Homalium* and its allies, and a single ocellus in the genus *Phlœobium*. The mandibles vary in form according to the habits of the species; they are usually strong, often sharply curved and pointed at the end, and of a distinctly carnivorous type. Attached to the base and running a little way alongside the inner margin of each mandible, there is to be seen in many species a narrow flexible plate fringed, or not, with hairs at the end. This piece, first made known by Kirby, who called it the *prostheca*, is rarely met with except in the *Staphylinidæ*. The ligula is narrow, and bears distinct paraglossæ; and the outer lobe of the maxilla is never palpiform. The rove-beetles are for the most part carnivorous, and prey upon all kinds of larvæ and other insects, as well as upon slugs, snails, and worms, but they feed largely on carrion, and to some degree on vegetable matter. Several species live in fungi, some in flowers, others under bark and in rotten wood, while in the case of certain genera, such as



BRITISH ROVE-BEETLES.

1, The devil's coach-horse (*Ocypus olens*); 2, *Staphylinus pubescens*; 3, *Philonthus æneus*; 4, *Oxyperus rufus*; 5, *Pæderus riparius*; 6, *Staphylinus cæsareus*. (Nos. 3, 4, and 5, slightly enlarged.)

Lomechusa and *Atemeles*, the species are to be sought for in or about ants' nests. Some of these latter species are welcome guests, since, like the Aphides, they secrete a liquid which is eagerly swallowed by the ants; others may possibly act as scavengers. Amongst the species of the genera *Spirachtha* and *Corotoca*, which live with the Termites in South America, some are very remarkable from the fact that the females give birth to living young.

Many of the British species of beetles belong to this family. Every one has seen the devil's coach-horse, that long, black, ugly-looking but useful insect which is to be found under stones and earth, or roving about in gardens, and which when you attempt to stay its progress, by pointing with a stick or finger, stands with threatening jaws and upturned tail as if ready to accept the challenge. This species which, with a few others, is represented in the figure, is scientifically known as *Ocypus olens*, and is one of the largest of the rove-beetles. Its habit of turning up the tip of the abdomen is not peculiar to it, but is common to nearly all the beetles of the family, which on that account are sometimes called cock-tail beetles.

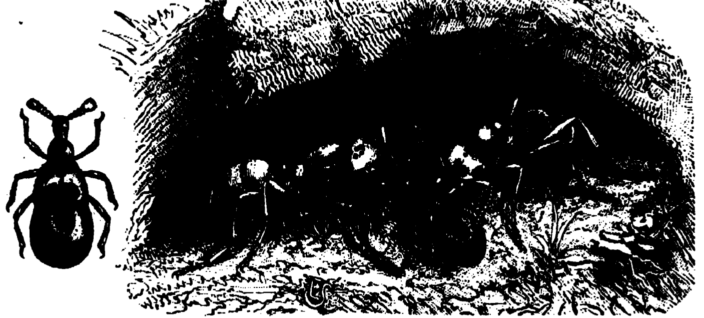
We come now to a series of small families, forming the group known as the Clavicornia or Necrophaga. This group, however, rests on no true scientific basis,

and is more or less artificial in its character. Most of the species included in the group feed upon decaying animal or vegetable matter, hence the name Necrophaga. The antennæ exhibit in general a tendency to be thickened towards the tip, and in many cases the last three joints form a distinct club; but in some of the families antennæ of quite another shape are to be found. Though usually five-jointed, the tarsi display in the number of their joints almost every variation met with in the Coleoptera.

The family of *Paussidæ* includes probably less than two hundred known species, the majority of which have been discovered in the tropics of Asia and Africa, though one species (*Paussus favieri*) occurs in the south-west of Europe. They are mostly reddish brown insects, of rather small size, oblong form, and in general appearance little attractive, were it not for the extraordinary shapes of their antennæ. These organs are generally very broad and flat, in some species resembling a paper-knife in shape; the number of joints varies from ten to two, and the last joint frequently has a bulbous or discoidal form. So far as at present known, all the species live in ants' nests, and, unless sought for in these situations, they are rarely seen except at night when they occasionally fly into rooms, attracted by the light from the lamps.

The tiny beetles belonging to the *Pselaphidæ* resemble the *Paussidæ* in exhibiting certain anomalies in their structure, and their lives are passed in similar obscure situations. But while the *Paussidæ* may possibly be related to the *Carabidæ*, the very short elytra of the *Pselaphidæ*, and the entirely horny nature of the dorsal plates of the abdomen seem to indicate an affinity with the *Staphylinidæ*. In other points of structure, however, these two families are different. In the *Pselaphidæ* the lobes of the maxillæ are soft and membranous; and the abdomen, which in one group (the *Clavigerinæ*) is composed of five segments, with the basal rings fused together, is quite incapable of the movements so characteristic of the rove-beetles. The joints of the antennæ vary in number from eleven to six, or even two, and are in most cases clubbed at the end. While in one division of the family the palpi are usually composed of three or four joints, and are long and conspicuous, in the other they are one-jointed and scarcely visible. The tarsi are three-jointed, the first and second joints often very short, while the third is long and in many cases bears only a single claw. The *Pselaphidæ* are distributed throughout most parts of the world. They are to be found under stones, moss, dead leaves, and other vegetable refuse, as well as under the bark of trees, and in damp marshy situations; but the most interesting species are those which live in ants' nests. They are all of small size. The genus *Claviger*, comprising about eighteen European and one or two Asiatic species, has six-jointed antennæ, and is further remarkable for the fact that the long cylindrical head is entirely devoid of eyes. The best known species, *C. testaceus*, is in Britain met with chiefly in the nests of the common yellow ant (*Lasius flavus*), though on the Continent it is found also in the nests of other species. It is about a tenth of an inch long, yellowish brown in colour, wingless, with the elytra fused together, and with a deep impression on the base of the abdomen. The relation between the ants and their guests is of a most interesting character. Whenever an ant meets one of these guests in a gallery of the nest, it gently

touches and caresses it with its antennæ, and while the beetle responds in a similar manner, the ant sucks at the tufts of hair near the end of the beetle's elytra, and then licks the whole anterior surface of the back of its abdomen. The ants feed the beetles in very much the same way as they feed their larvæ. When the beetle is hungry it expresses its desire to be fed by licking an ant near the mouth, and occasionally stroking the sides of its head with gentle movements of its antennæ. During the process of feeding the beetle is passive; the ant moves its head gently to and fro, while the head of the beetle rests almost motionless in its mouth. The attention bestowed by the ants on the beetles is as great as that which they give to their own larvæ, and they frequently feed the hungry ones among them, before looking after the wants of their own brood.



Claviger testaceus, caressed by ants (greatly enlarged).

The orange-banded burying-beetles of the genus *Necrophorus* are probably the best-known members of the *Silphidæ*, though they are not to be considered the most representative, either in habits, size, or general appearance. The many genera of which the family is composed differ greatly in size and outward form, while the burying instinct is almost entirely confined to the genus *Necrophorus*. In nearly all cases, however, the antennæ, consisting usually of eleven joints, are thickened towards the tip or furnished with a distinct club; the prothorax is usually broad and flat, with sharply defined lateral margins, while the elytra frequently do not reach to the tip of the abdomen; the coxæ of the four anterior legs are large, prominent, and conical in shape; and the tarsi are usually five-jointed, though occasionally with a less number of joints. The Carrion-beetles are widely distributed, though chiefly characteristic of the colder and temperate zones. In the genus *Necrophorus* the antennæ terminate in an almost globular, four-jointed mass; the body is broadest across the ends of the elytra, which are abruptly truncated, leaving the tip of the abdomen exposed. The species of this genus are black in colour, but in most of them the elytra are crossed by two broad orange bands. They feed upon dead animals of all kinds, and their habit of burying the smaller carcases, such as those of mice, moles, small birds, etc., has gained for them the name of "sexton" or "burying" beetles. Their mode of operation is to creep underneath and dig the earth away until they have made a hole big enough to receive the dead body; as the latter sinks, the loose soil closes over it and in time completely hides it from view. The females then lay their eggs in the carcase, which subsequently serves as food for the larvæ. These insects must have a very acute sense of smell, for in a very short time after a mole has been killed some of them may be seen hovering over the body, although not previously observed anywhere in the vicinity. Out of about a dozen species of *Necrophorus*

occurring in Europe, seven are found in Britain, *N. vespillo* being perhaps the one which is most widely distributed. Most of the species of the genus *Silpha*—from which the family name is derived—are dark, sombre-looking insects, somewhat ovate in shape, the prothorax being broad and closely applied to the base of the elytra, while the elytra usually extend to the tip of the abdomen. The head is small, and when turned down is hidden under the pronotum. The beetles themselves are generally met with in or about dead animals, but some of the species display a partiality for a vegetable diet; thus in France the adult *Silpha reticulata* has been found to attack wheat, while *Silpha nigrita* devours strawberries in the Alps and Pyrenees. The larvæ of most of the species are somewhat like wood-lice in shape, with the posterior angles of the abdominal segments sharply produced. Those of *S. opaca* and *S. atrata* are sometimes very destructive to the leaves of sugar-beet and mangold-wurzel.



Silpha atrata and larva (rather less than nat. size).

The *Trichopterygidæ*, or hairy-winged beetles, are exceedingly minute insects, the smallest, in fact, of all the beetles, many of the species being less than the fiftieth part of an inch in length. They are further remarkable on account of the structure of their wings. These organs are very long and narrow, each consisting of a strip of membrane attached to a horny stalk and fringed on each side with long and closely-set hairs.

The *Histeridæ* form a well-defined family, widely distributed, and numbering considerably more than twelve hundred species. In colour they offer little variety, being mostly either black, dark blue, or green, the elytra being occasionally spotted with red or yellow. They are compactly oval or oblong-oval in form, and nearly always present a highly polished appearance. The antennæ are short, with a long basal joint and a very distinct terminal club, and as a rule are capable of being turned back into grooves beneath the thorax. The elytra are truncate at the tips, leaving the last two segments of the abdomen exposed; they are generally marked with a series of finely impressed longitudinal lines, the number and disposition of which afford useful



Hister fimetarius and larva (nat. size).

characters in distinguishing between the different species of a genus. In the division of the family to which *Hister* belongs, the prosternum is produced in front, forming a prominent "chin-piece" which serves to protect the lower part of the head when the latter is retracted. In *Saprinus* the "chin-piece" is wanting.

The *Nitidulidæ* have some resemblance in external form to the *Histeridæ*, though they are generally of smaller size, with their integuments less hard, and their colours a little more varied. The elytra are slightly truncate behind, leaving a variable number of the segments of the abdomen exposed. The antennæ are eleven-jointed or, exceptionally, ten-jointed, with the last two or three joints forming a knob; the maxillæ have as a rule but a single lobe, and the tarsi are five-jointed, though in a few genera the males, at least, have only four joints in the posterior tarsi. Many of the species are found feeding and breeding in decaying vegetable or animal substances, such as rotten wood, bark, fungi, and in carcases or bones; some frequent the exuding sap of trees; while a very large number are to be seen on flowers, amongst which are the brightly-coloured little beetles of the genus *Meligethes*. The species figured (*M. æneus*) is one of the commonest, and met with chiefly on the flowers or leaves of cruciferous plants. In Germany these little beetles are well known, on account of the depredations they commit in crops of rape. A few days after emerging from their winter sleep, the beetles lay their eggs in the buds; in about a fortnight the larvæ are hatched and proceed to feed on the undeveloped or full-blown flowers; while later on they attack the young pods, to which they do more damage than the beetles themselves. The small family *Byturidæ* may also be mentioned here. The genus *Byturus* contains only four or five known species, which are confined to Europe and North America, and one of which is familiar to gardeners and others as the "raspberry beetle." This species (*B. tomentosus*) is somewhat oblong in form, from an eighth to a sixth of an inch in length, of a dirty yellowish colour, and covered with a yellow down. Though found on flowers of many different kinds, it is especially common on raspberry blossoms, and the cylindrical brownish larvæ sometimes do much damage to the flowers and fruit.



Meligethes æneus (nat. size and greatly magnified).

The *Dermestidæ* have a special interest, owing to the destructive habits of many of the species. The beetles themselves are small in size, oblong or oval in shape, sometimes nearly round, and usually clothed with fine closely lying hairs or scales, which frequently give rise to greyish or yellowish spots or bands on the elytra. The front of the head, except in the genus *Dermestes*, bears a single

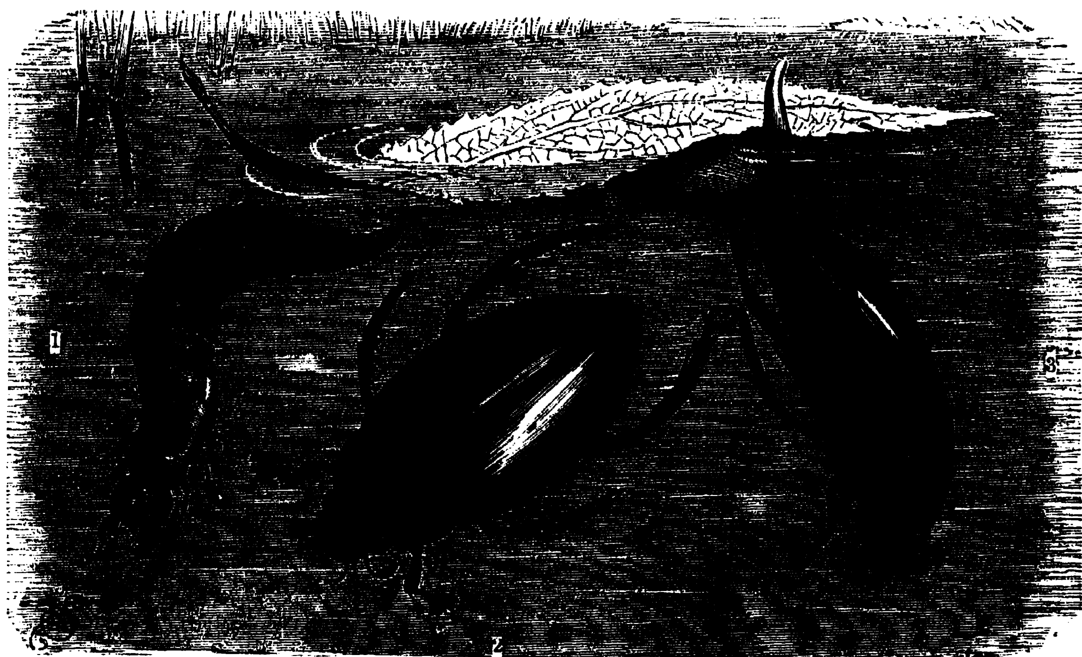
ocellus; the short antennæ, consisting usually of eleven joints, are clubbed at the end; the abdomen is entirely covered over above by the elytra; and the tarsi are always five-jointed. While certain species are met with only on flowers, the majority live in dried animal matter—furs, skins, and the like, as well as articles of food, such as bacon and cheese. The perfect insects do comparatively little damage, the real depredators being the larvæ, including those of many species which in the adult state frequent flowers. The larvæ are little hairy creatures of a dark colour, looking like small caterpillars, with the hairs sticking out straight and arranged more or less in tufts or bundles. The larvæ of *Anthrenus musæorum*, the so-called museum-beetle, have to be carefully guarded against in museums, as they are very destructive to zoological collections and more especially to those of dried insects. *Attagenus pellio* is another very common species of this family, usually found in houses, and well known on account of the ravages of its larva in natural history collections, furs, hair-stuffed couches, etc. The larva is of a brown or red-brown colour above, and covered with long hairs pointing backwards; it is broader in front and tapers towards the hinder end, where it carries a tail-tuft of very long hairs.

In the *Hydrophilidæ* the antennæ are short and composed of from six to nine joints, of which the first is relatively long, and the last three or so thickened in the form of a club; the mentum is a large shield-like plate without a notch in front; the lobes of the maxillæ are not toothed, and the palpi are long and slender, frequently much longer and more conspicuous than the antennæ. These characters afford a ready means of distinguishing these herbivorous water-beetles from the carnivorous water-beetles, to which in general shape many of them bear a close resemblance. The great length of the maxillary palpi has given rise to the name *Palpicornes* by which the family was formerly known. In the perfect state, all the members of the family feed upon vegetable matter; but it is only those of the subfamily *Hydrophilinæ*—of which the great water-beetle, *Hydrophilus piceus*, may be taken as the type—that are truly aquatic in their habits; the second subfamily, the *Sphæridiinæ*, though including certain marsh-frequenting species, is composed mainly of land-insects which are found chiefly in vegetable refuse or in the droppings of herbivorous mammals. Of the *Hydrophilinæ* some are found in stagnant, others in running water, but they are nearly all poor swimmers, while a large number progress by simply crawling along the surface film upside down; in their slow movements they present a marked contrast to the active predatory *Dytiscidæ*.

Having touched upon the principal families of the Clavicorn series, we pass to the Pectinicornia, a small tribe containing only two families, one of which has no European representative, while both are somewhat limited in the number of their species. In the *Lucanidæ* the antennæ are ten-jointed, with the first joint long and set at an angle with the rest of the antennæ, of which from three to seven of the last joints are furnished with rigid tooth-like processes on one side. The outer lobe of the maxillæ ends in a pencil of hairs, while the inner lobe has very often the form of a claw; the ligula is membranous or leathery in texture, and is attached to the inner face of the mentum; the elytra cover over the abdomen, which on the ventral side shows five or, in the male, six segments;

and the tarsi are five-jointed, with a long slender spur projecting between the claws of the terminal joint, and carrying at the end two long bristles. The male insects are remarkable for the massive development of their jaws, which in many cases are forked and branched. The common stag-beetle (*Lucanus cervus*), one of the largest of European beetles, may, in the case of full-sized males, attain a length of over 2 inches, or, if the mandibles be included, more than 3 inches. It is most abundant in the neighbourhood of oak-woods, and in England is not uncommon in the southern counties, where the males may be often observed on the wing on fine summer evenings, flying with a loud hum.

The *Passalidæ* are a small family of about two hundred known species, which are almost entirely restricted to the warmer parts of the world, the greater pro-



GREAT BLACK WATER-BEETLE (nat. size).
1, Larva. 2, Male. 3, Female with egg-cocoon.

portion being found in America. In the form of the antennæ and in some other respects they show an affinity with the *Lucanidæ*, though easily distinguished by the character of the mouth-parts. The ligula is horny, and lies in a deep quadrangular emargination in the mentum; the lobes of the maxillæ both resemble claws; and the mandibles offer a peculiarity of structure met with in no other family, each being provided with a movably articulated tooth placed close to the basal molar surface.

The Lamellicornia—comprising the burrowing-beetles, cockchafers, and a host of other forms, differing both in habits and external structure—are represented in all parts of the world, though relatively less numerous in Australia than in the other great regions. We have only to mention the goliath-beetles of West Africa, and the elephant and hercules-beetles of Tropical America, to indicate the great size attained by some of the species; while as regards beauty and brilliancy of

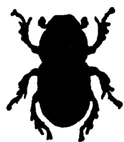
coloration no beetles can rival many of those belonging to the two subfamilies *Cetoniinæ* and *Rutelinæ*. The male stag-beetles, as we have just seen, are distinguished by their large heads and monstrous jaws, but in the males of the present family it is as a rule the prothorax which is greatly enlarged or otherwise modified in form, and often furnished, like the head, with processes of various kinds, sometimes short, in others taking the shape of huge curved or branching horns. The family admits of two principal divisions. In the first division the ligula of the lower lip is more or less membranous and distinct from the mentum, and the spiracles of the abdomen are all situated in the connecting membrane between the dorsal and ventral plates. Among these we may mention the genus *Scarabæus*, over sixty species of which are known, most of them African, some occurring in Asia, and a few, including *sacer*, one of the sacred beetles of the Egyptians, found also in South Europe. Amongst the coprophagous species, met with in Great Britain, those of the genus *Aphodius*, which represents a second subfamily, are the most numerous. They are somewhat oblong in form, as shown in our figure of *Aphodius fossor*, one of the largest and best-known species, and are usually shining black, though in many the elytra are of a reddish or yellow colour, in some cases spotted with black. A type of another subfamily is found in the genus *Geotrupes* of which we have in this country several species, including the well-known "dumble-dor" or "shard-born" beetle (*G. stercorarius*). The species almost all exhibit dark blue or black colours, and in most cases the sexes differ little in external form; but in *G. typhæus*, the male is distinguished by having three horns projecting from the prothorax. The plant-feeding or phytophagous subfamilies belong to the second division of the *Scarabæidæ*. In these the ligula is consolidated with the mentum, and the abdominal spiracles are placed, some in the connecting membrane between the dorsal and ventral plates, the others on the sides of the ventral plates. One of our most familiar insects, the common cockchafer, gives a good idea of the general form and style of coloration prevailing in the subfamily *Melolonthinæ*, while in habits also it resembles other species of the same group. As examples of some of the other *Melolonthinæ* we figure *Polyphylla fullo*, one of the finest European species, which, though not indigenous to Britain, has occasionally been found on the south coast, and—on p. 144—*Rhizotrogus solstitialis*, a common British insect, commonly known as the summer-

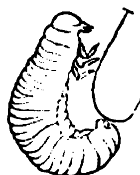


BURROWING BEETLE, *Scarabæus variolosus* (nat. size).



Scarabæus sacer (nat. size).





Aphodius fossor, with larva (enlarged).

chafer. The *Rutelinæ* have some resemblance in external form to the *Melolonthinæ*, but can in general be easily recognised owing to the difference in length between the two claws of each of their tarsi. The *Dynastinæ* are mostly confined to the warmer parts of the world, and chiefly remarkable on account of the great sexual differences exhibited by the species. In the hercules-beetles (*Dynastes hercules*), of the West Indies and Tropical America, the male is sometimes over 5 inches long. The elephant-beetle is a more massive insect, though, having relatively much shorter horns, its total length is not so great. As compared with other species of the subfamily the European rhinoceros-beetle (*Oryctes nasicornis*), figured on p. 144, is very modest in its proportions. Our next subfamily, the *Cetoniinæ*, stands unrivalled amongst the Coleoptera for the loveliness of coloration displayed by many of its species. The goliath-beetles belong to this subfamily. In some of the genera, such as *Ceratorrhina* and *Goliathus*, the males may be recognised by the shape of the head, which is often excavated above, and furnished with hooks or horns, as shown in *C. smithi* on p. 145.



MALE OF *Geotrupes typhœus* (nat. size).

The *Buprestidæ*, together with the click-beetles (*Elateridæ*), and a few smaller families, constitute the tribe Serricornia. Distinguished chiefly by their serrated or flabellated antennæ, the beetles of this tribe agree also in having the tarsi five-jointed, and the prosternum prolonged behind and fitting into a cavity of the mesosternum. They are generally of an elongated form, with the elytra narrowed from the base to the tip and completely covering the abdomen. The *Buprestidæ* have short, serrated antennæ, composed of eleven joints, which, with the exception of three or four nearest the base, are covered on special areas with very minute pits supposed to be of an olfactory nature; these areas may be spread over nearly the whole of each joint, or confined to one side or the end of the joint, and their position affords one of the most important characters used in the classification of the family. The family is divided into three principal groups — the *Julodinæ*, *Chalcophorinæ*, and *Buprestinæ*. The first group is chiefly restricted to Africa and the East Indies. The *Chalcophorinæ* are more widely distributed, and include many of the finest species of the family, such as the *Euchroma gigantea* of South America, and the species of *Catoxantha* found in the East Indies. *Chalcophora mariana*—figured on p. 145—occurs in many pine-forests of the Continent, and is one of the largest European species. The *Buprestinæ* are more numerous than the other two groups, and are found in all parts of the world.



Polyphylla fullo, male (nat. size).

The click-beetles are, as a rule, narrower and more elongated than the

Buprestidæ, and differ also in having the posterior angles of the pronotum sharply produced behind, and the prosternal process laterally compressed and slightly curved, with its point resting in a deep cavity in the mesosternum. Their antennæ —consisting of eleven, or rarely twelve, joints —are usually serrate, though in many cases, especially in the males, they are either pectinate or flabellate. These beetles owe their name of skip-jacks to the power they have, when fallen on the back, of springing into the air and alighting on their legs again. The larvæ of some species eat into soft succulent roots and tubers, and in this way prove destructive to many of our cultivated plants. These pests are well-known to farmers under the name of wire-worms. The larva of *Agriotes lineatus* is one of the worst, being destructive not only in the fields but also in the kitchen-garden. It is of a pale yellowish brown colour, differing little in general appearance from the larvæ of other species, and lives for probably four or five years, passing then into a pupa, which remains concealed in the ground for a few weeks before changing into the perfect insect. Amongst the exotic members of this family, the most remarkable are the fire-flies, found in the West Indies and America. There are several species of these beetles, all belonging to the genus *Pyrophorus*, one of which, *P. noctilucus*, is illustrated on p. 146. They have a dark brown or reddish brown colour, obscured by a covering of short grey hairs, and may be easily recognised by the two slightly raised yellow spots placed near the hind angles of the prothorax. In the living insect these spots glow with a rich yellowish green light. A stronger but more diffused light of a reddish colour is given off from the abdomen when the beetles are flying.



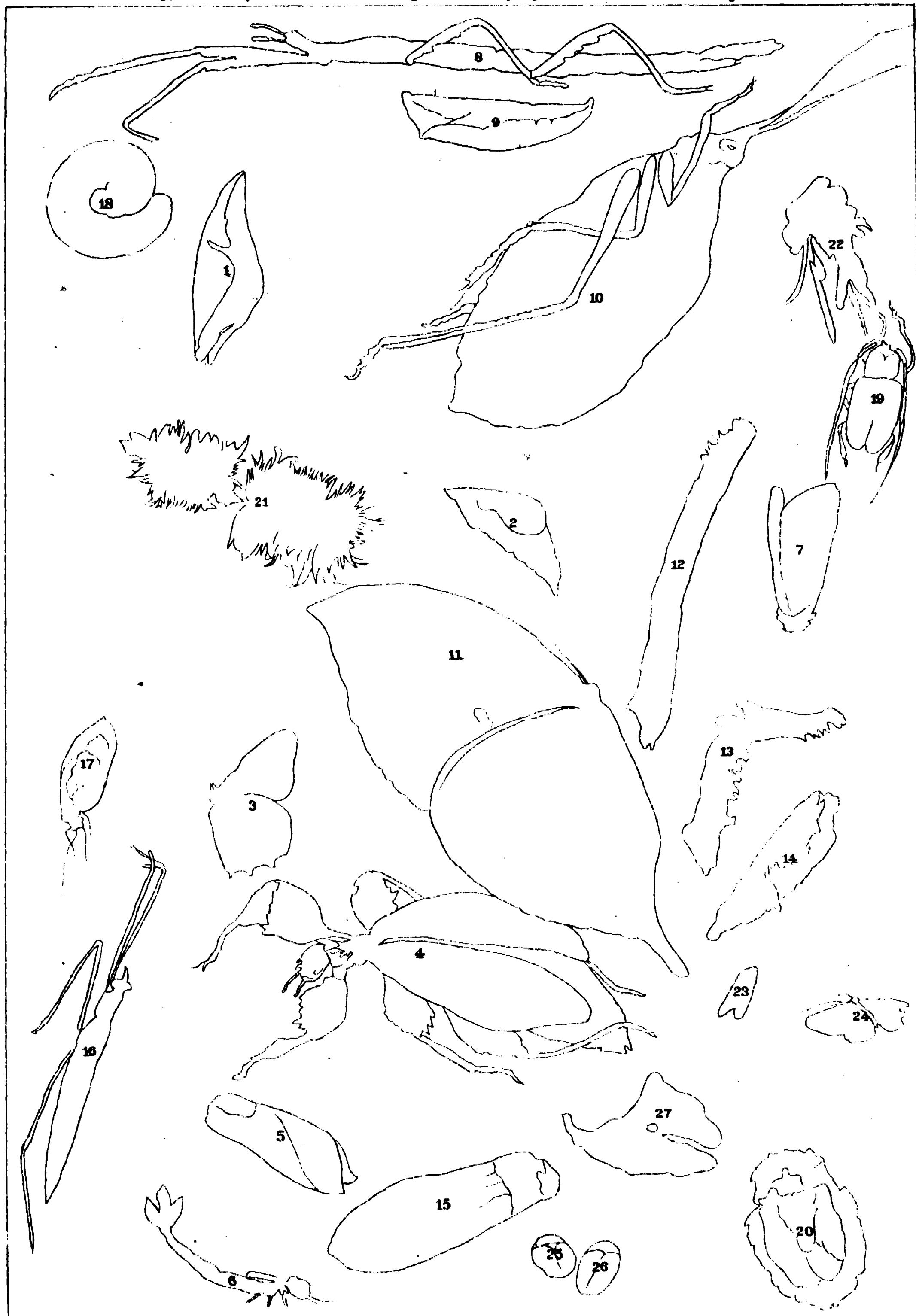
SUMMER-CHAFER (nat. size).

The remaining families of the section Pentamera are included in the tribe Malacodermata. The beetles of this tribe are distinguished by having the elytra less solid and compact, and the body in general softer and more flexible than is usual in other groups. The *Lycidæ* are deserving of notice, inasmuch as they form one of those groups of insects which are most frequently mimicked by species of other families. They have a characteristic appearance, owing to the small size of the head and prothorax, as compared with the greatly expanded elytra. To their unusual shapes these beetles generally add a conspicuous coloration;



RHINOCEROS-BEETLE, male (nat. size).

1. Chrysalis of *Apatura ilia.* 2. Chrysalis of *Rhodocera rhamni.* 3. Green Hairstreak Butterfly, *Thecla rubi.* 4. Leaf Insect, *Phyllium siccifolium.* 5. Green Silver Lines Moth, *Halias prasinana.* 6. Young Dragon-Fly. 7. Scarce Merveil du Jour Moth, *Moma orion.* 8. Stick Insect, *Bacillus rossii.* 9. Chrysalis of *Papilio podalirius.* 10. Leaf-like Locust, *Pterochroza colorata.* 11. Dead-leaf Butterfly, *Kallima philarchus.* 12. Caterpillar of *Arapteryx sambucaria.* 13. Caterpillar of *Notodonta ziczac.*

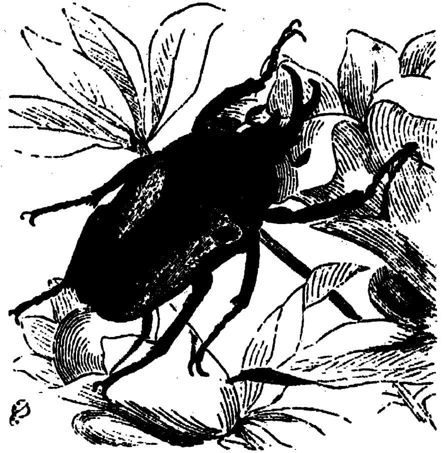


14. Chrysalis of *Papilio evander.* 15. Buff-tip Moth, *Phalera bucephala.* 16. Water-Bug, *Ranatra linearis.* 17. Dead-leaf May-Fly, *Drepanopteryx phalænoides.* 18. Larva of *Cimbex betulæ.* 19. *Mesosa cerculionoides.* 20. *Phlæa corticata.* 21. *Pemphigus xyloste..* 22. Psychid caterpillar. 23. *Tortrix ocellaria.* 24. Clouded Border Moth, *Abraxas marginata* 25. Histerid Beetle. 26. Byrrhid Beetle. 27. Cocoon of *Aides amanda.*



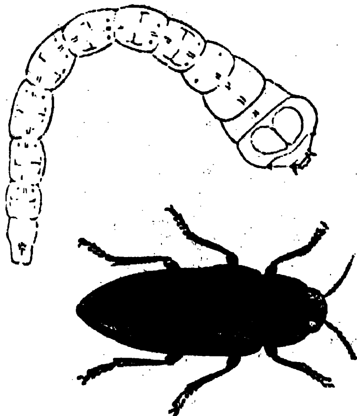
MIMICRY IN INSECTS.

tawny yellow and red, varied in many cases with black spots and bands, being the predominant colours throughout the family. They are found on the flowers and leaves of trees, and are sometimes seen in great abundance; and it is said that they secrete a nauseous liquid, which gives them immunity from the attacks of insectivorous animals.



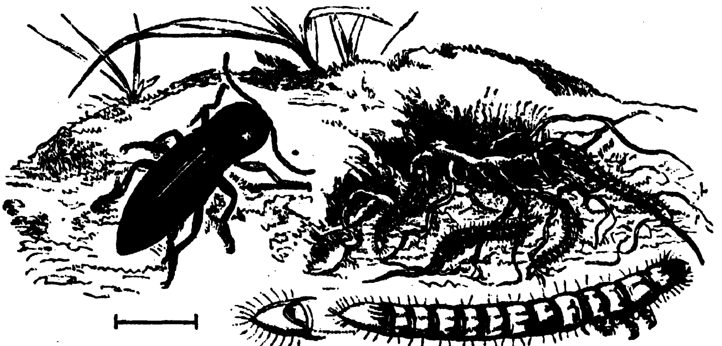
Ceratorrhina smithi, male.

The *Lampyridæ* are remarkable on account of the luminous properties possessed by nearly all the species. In these insects the head is small and, being retracted under the pronotum, generally invisible from above; the eyes are large, especially in the males, the mandibles small but sharply pointed, and the antennæ come off close together from the front of the head. The phosphorescent organs are situated in the abdomen, their position being shown in most of the species by pale yellowish or whitish areas on the ventral surface of certain of the segments. These beetles are found in nearly all parts of the world, though most numerous perhaps in Tropical America. In *Lampyris* and certain other genera the females are frequently apterous. The female of *Lampyris noctiluca*—our native glow-worm—is not only without wings, but has even no trace of elytra, so that in appearance it is not unlike the larva of the same species, though it may be distinguished by its broad semicircular prothorax, its more fully developed legs, and much greater luminosity. In the genus *Lucicola*—which is represented by two or three species in South Europe—both sexes are winged, and the males are even more luminous than the females.



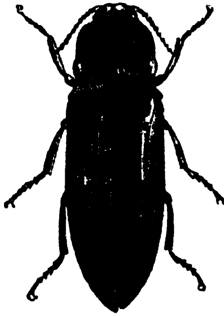
Chalcophora mariana and larva (nat. size).

The *Telephoridæ* are distinguished from the two preceding families in having the head more exposed, the bases of the antennæ more widely separated from one another, the pronotum somewhat square in shape, the maxillary palpi ending in a hatchet-shaped joint, and the mandibles longer and often bifid at the end, or toothed on the inner side. Some of them are among the commonest and most familiar of our insects, — being known to schoolboys as "soldiers"

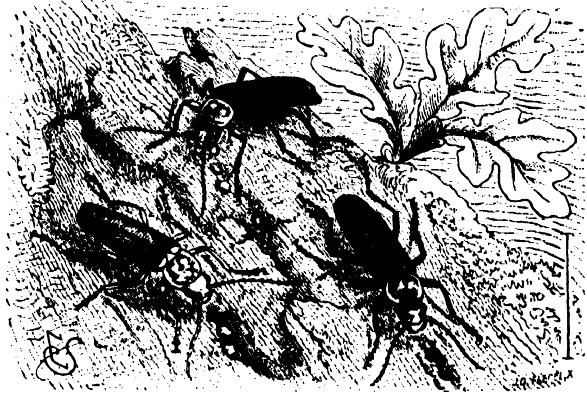


Agriotes lineatus and its larva—the well-known wire-worm. (Both much enlarged, but the larva shown also nat. size.)

and "sailors," —and few of our readers can fail to recognise the species figured. This species (*Telephorus fuscus*), and a few others of the same genus,—some of



THE WEST INDIAN FIRE-FLY, *Pyrophorus noctilucus* (nat. size).



Telephorus fuscus (slightly enlarged).

which are of an almost entirely yellowish red colour,—are very plentiful on flowers at certain times of the year.

The *Cleridæ* are generally brightly coloured, of cylindrical form, with the prothorax narrower than the elytra, the eyes notched in front, the antennæ either serrate, pectinate, or clavate, and the tarsi furnished underneath with membranous lobes. *Clerus formicarius* is very abundant in pine-forests, where it plays a useful part in hunting for and devouring wood-boring beetles; while the larva is still more active in following under the bark the larvæ of various kinds which are there to be met with. The second species figured (*Trichodes apiarius*) hunts for its prey on flowers, especially those of the *Umbelliferæ*, and the larvæ are found in beehives, where they devour many of the young brood.

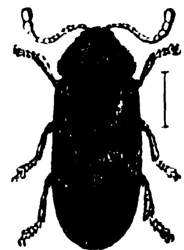


Clerus formicarius, with larva and pupa (all enlarged).



Trichodes apiarius (enlarged).

The *Ptinidæ* are all small insects, usually of a somewhat cylindrical form, rounded at each end, and with the head retracted under a hood-like covering, formed by the prothorax. They are obscurely coloured and chiefly interesting on account of their mischievous propensities. In the larval state *Ptinus fur* is very destructive in herbaria, and natural history collections generally. The best known of the *Ptinidæ* are the death-watch beetles of the genus *Anobium*, to which we have already referred at the beginning of this chapter. These beetles seldom show themselves openly, so

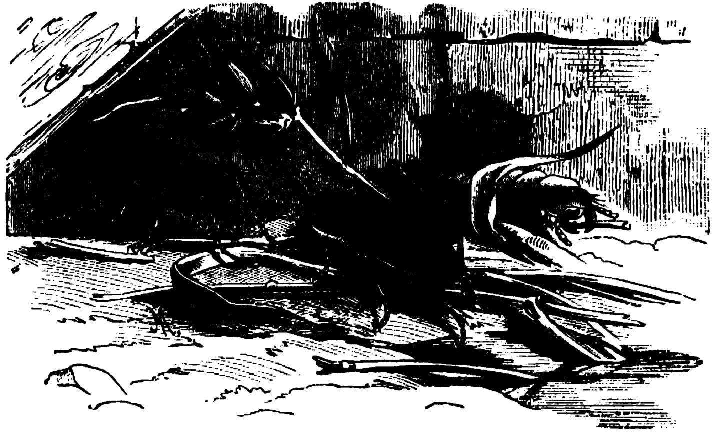


THE DEATH-WATCH BEETLE, *Anobium tessellatum* (enlarged).

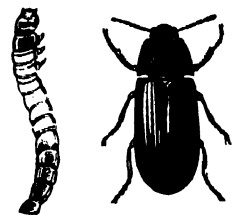
that to most people they are only known by the sounds they produce, or the holes with which the larvæ riddle furniture and the woodwork of houses. The holes with which old books are sometimes seen to be perforated are also made by the larvæ of a species of *Anobium*, which for this reason are known as book-worms.

SECTION HETEROMERA.

The Heteromera are those beetles in which the tarsi of the fore and middle-legs are five-jointed, those of the hind-legs being four-jointed. The *Tenebrionidæ* exceed in number of species the rest of the Heteromera together. The antennæ are inserted under a projecting angle or ridge on each side of the head, and composed of eleven or, exceptionally, ten joints, of which the third is generally the longest; the coxæ of the front-legs are usually rounded, with their sockets separated by a fairly broad prosternal process, and completely closed in behind; and the claws of all the tarsi are simple. Many of the obscurely coloured species are without wings, and frequently have the elytra fused together. The churchyard beetles (*Blaps*) and the meal-worm (*Tenebrio*) are probably the best known members of the family. *B. mucronata* is the commonest species in England; it differs from *B. mortisaga*, which also occurs, though rarely, in this country, in having shorter points to the elytra. Of the genus *Tenebrio* two species occur in Britain, one of which (*T. molitor*) is almost cosmopolitan in its range, having been carried in flour to nearly every part of the world. The larvæ, known as meal-worms, are long and narrow, of a light yellowish red colour, with the integument hard, and the last segment conical in shape and ending into two slightly diverging processes, armed each with a small black spine.



CHURCHYARD BEETLE AND LARVA (nat. size).



THE COMMON MEAL-WORM AND ITS LARVA (enlarged).

The *Rhipidophoridæ* are a small but interesting family of beetles in which the wings are always more or less exposed, and not folded transversely as in most other groups, while the elytra are either very short (as in the genera *Rhipidophorus* and *Rhipidius*), or else triangular in form, meeting only at the base and diverging from one another behind.

The *Meloidæ* are chiefly distinguished from the other Heteromera by having the head abruptly constricted behind in the form of a short neck, the coxæ of the anterior and middle legs long and prominent, and placed close to one another in

the middle line, and the claws of the tarsi accompanied each by a slender hook, so that they appear double. Many of the species possess vesicating or blistering properties, and the family is for this reason sometimes known as the *Vesicantia*. The larvæ are interesting on account of their habits and the changes of form they undergo in the course of their development. These changes are well illustrated in the case of the oil-beetles (*Melöe*). The larvæ of these when first hatched from the egg are active little creatures furnished with six legs. They climb on to flowers, and wait in readiness to fasten themselves to the hairs of bees coming to gather the honey. In this way they get carried to the nest, where they devour the eggs of the bee. They now cast their skin, appear as little, maggot-like



OIL-BEETLES AND LARVÆ (nat size).

grubs, with much reduced legs, and feed on the honey intended by the bee for its own young. After a time they change to the form of a pupa, from which, instead of the perfect insect, a third form of larva, somewhat similar to the second, emerges, while a further change is still required before the true pupal stage is reached. Seven species of *Melöe* occur in Great Britain, but, with the exception of one or two, are very rare. When handled or irritated they exude an oily-looking liquid of a yellow colour from certain of their joints. This secretion, to which they owe their name of oil-beetles, has a burning, acrid taste.

The *Stylopidæ* are remarkable little insects, which live parasitically in the bodies of wasps, bees, and bugs, and present a type of structure distinct from that of all other beetles. The male is a winged insect, with coarsely-faceted prominent eyes, large fan-shaped wings, and extremely small inconspicuous elytra; the first two thoracic rings are very short, while the metathorax is greatly elongated and covers over the base of the abdomen; the hind-legs are placed a long way behind the middle pair, and the tarsi of all the legs are membranous under-

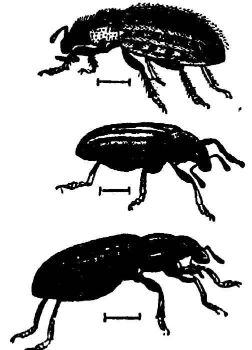


1, *Xenos peckii*—male; 2, female. (Both enlarged.)

neath, and without claws at the end. The female, on the other hand, is a grub-like creature, without legs, wings, or eyes. She never leaves the body of her host, and from her eggs active little six-legged larvæ develop, which make their way out and get carried into the nests of bees and wasps, where they bore into the bodies of the grubs. The *Stylopidæ* are very rarely seen, and the number of species known is small. They have been arranged in four or five genera, based upon slight differences in the structure of the males, all of which have the general appearance shown in our figure of *Xenos peckii.*

SECTION TETRAMERA.

The *Curculionidæ* or weevils are distinguished from all other beetles by a few well-marked characters. The head is always produced in front in the form either of a short muzzle or a more or less elongated and narrow beak, which carries the mouth at its extremity; the prothorax rarely has sharp lateral edges, and the coxal cavities on the under side of that segment are always closed in behind by the extension inwards of the epimera to meet in the middle line; and the antennæ are elbowed, with the first joint as a rule long, and some of the joints at the end forming a club. Though agreeing in a few essential characters, the weevils present considerable variety, not only in the form and structure of different parts, but also in the general shape of the body. They have been arranged in a number of subfamilies, but it is impossible in a limited space to describe the various modifications of structure on which these divisions are based, and we must content ourselves here with a brief reference to some of the typical and more interesting forms. In the genus *Sitones,* we have examples of those weevils in which the snout is short and comparatively broad. *S. lineatus* is a well-known species which lives on papilionaceous plants, and frequently does much mischief by devouring the young leaves of peas and beans. It is a little yellowish grey or drab-coloured beetle with three pale lines along the thorax, and a number of rows of punctures along the elytra. Its colour is due to a thick covering of scales, some of which, when looked at closely, are seen to have a golden tint.



Sitones lineatus and allied species.



PINE-WEEVIL, WITH LARVA AND PUPA.

Weevils are, as a rule, most destructive during the larval state, the adult insects doing a comparatively small amount of injury to vegetation; but as regards *Hylobius abietis,* known as "the large pine-weevil," one of the worst enemies of young conifers, the injury done to the trees is altogether the work of the beetles, while the grubs are quite harmless. The genus *Apion* comprises a large number of little, long-snouted weevils,

having in general the form shown in our figure of *A. apricans*. Though the British species are numerous and some of them common everywhere on clover, trefoil, and other leguminous plants, they are seldom noticed owing to their small size. In *Apoderus*, *Attelabus*, and *Rhynchites* we have a group of genera which are interesting on account of the leaf-rolling habits of the females, and remarkable also, in the case of the first genus, for the great length of neck displayed by some of the species. The females deposit a single egg, or in some cases two or even three eggs in each of the little rolled-up leaf packages, which serve afterwards both as a shelter and food-supply for the larvæ. Three or four species of these leaf-rolling weevils are found in Britain. Our figure of *A. longicollis*,



Apion apricans (nat. size and much enlarged).



LEAF-ROLLING WEEVILS.

1, *Attelabus curculionoides*; 2, *Apoderus coryli*; 3, *Rhynchites betuleti*; 4, *R. populi*; 5, *R. betulæ*. (Nat. size.)

a Javan species, shows what an extraordinary length the neck may attain in the males of some of the tropical representatives of the genus, although in this species it is not nearly so long in proportion as in an allied form (*A. tenuissimus*) found in the Philippine Islands. The nut-weevil (*Balaninus nucum*) affords a strong contrast in the shape of its head to the species just mentioned. It will be noticed that in this weevil the head is very short behind the eyes, whereas the beak is greatly elongated, with the antennæ inserted near the middle of its length. The female lays her eggs in hazel-nuts while the latter are still in a half-developed condition; she first pierces a hole in the soft shell of the nut, and then depositing an egg in the opening pushes it in with her beak. The grub feeds inside the nut, remaining in it until autumn, when it bores a round aperture in the shell, and, escaping from the nut, makes its way into the soil, where it surrounds itself with a cocoon formed of

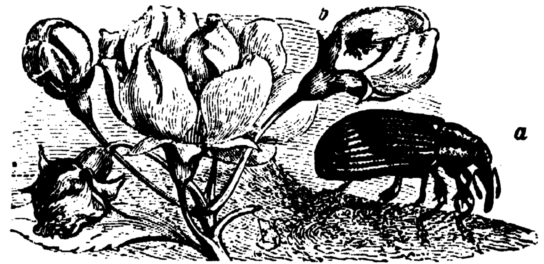


Apoderus longicollis (enlarged).

fragments of earth. The "apple-blossom weevil" (*Anthonomus pomorum*) is another species which, on account of its injurious habits, deserves some notice. It

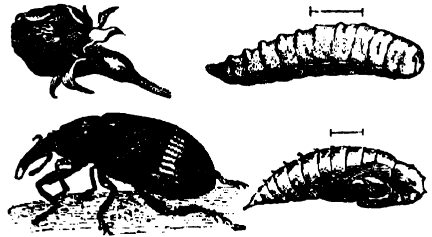


NUT-WEEVIL AND ITS LARVA.

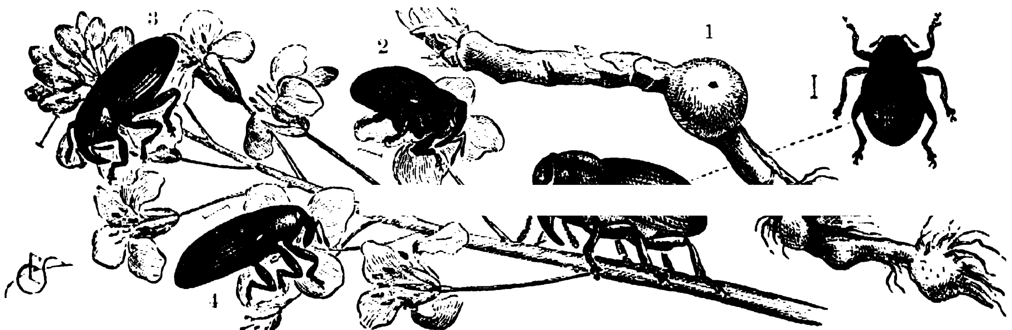


PEAR-BLOSSOM WEEVIL, WITH LARVA AND PUPA (enlarged).

is about a quarter of an inch long, of a greyish brown colour, with an oblique white band on the elytra, and three whitish lines on the thorax. The female deposits her eggs in the unopened flower-buds of the apple, and the larva by feeding on the stamens and pistil causes the bud to wither and die. In about fifteen days, the larva attains its full size, changing then to a pupa within the bud, and the beetle appears about eight days later and escapes through an opening which it makes in the side. A closely allied species (*A. pyri*) proves injurious in the same way to pear blossoms. The cabbage-gall weevil (*Ceuthorrhynchus sulcicollis*) and certain species of *Baridius* attack cruciferous plants; the larvæ of the former live inside galls which they raise on the roots of cabbages and turnips, while those of *Baridius* may be found living in the lower part of the stem. The grain-weevils, which are most numerous in tropical countries, are represented in Britain by two almost cosmopolitan species, the corn-weevil (*Sitophilus granarius*), and the rice-weevil (*S. oryzæ*). These are both small



APPLE-BLOSSOM WEEVIL (nat. size and enlarged).



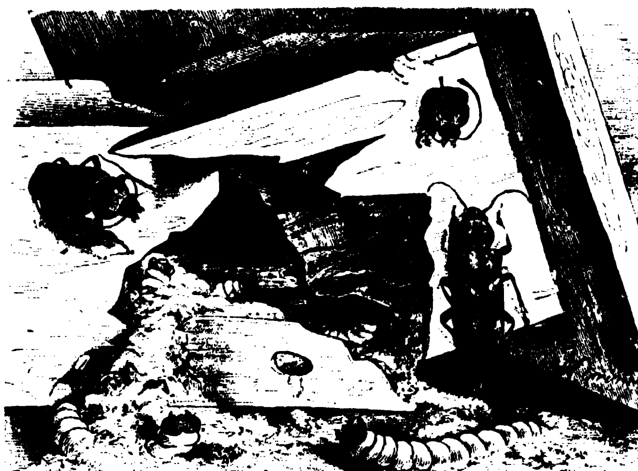
1. *Ceuthorrhynchus sulcicollis*; 2. *C. assimilis*; 3, *Baridius chloris*; 4, *B. cuprirostris*. (The beetles all enlarged.)

species, but belong to a subfamily (the *Calandrinæ*), which includes a number of the largest tropical weevils, such as the palm-weevil (*Rhynchophorus palmarum*).

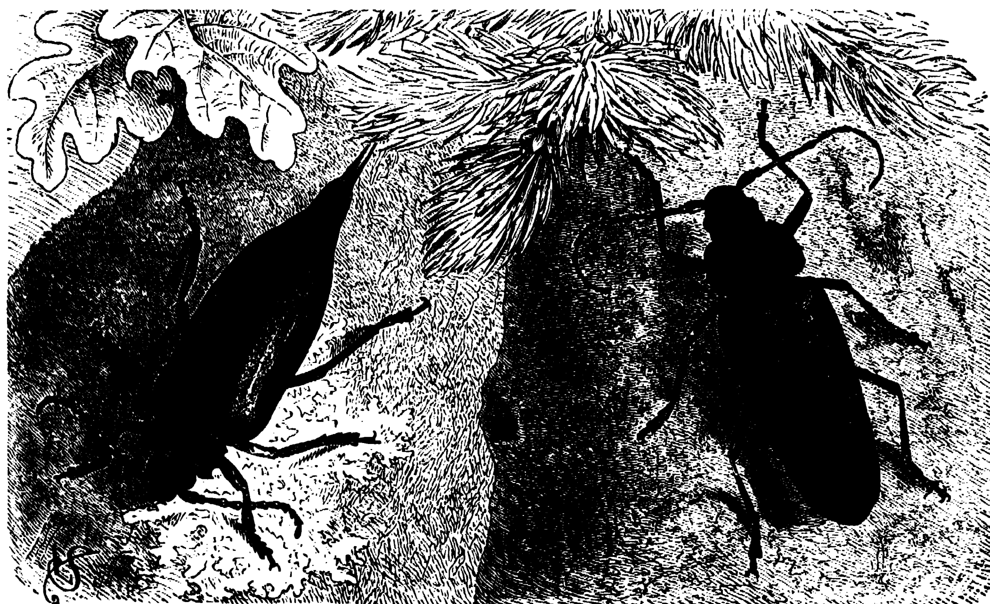

PALM-WEEVIL (nat. size.)

The *Scolytidæ* and two other small families, the *Brenthidæ* and *Anthribidæ*, are associated with the weevils in the tribe Rhynchophora. The *Scolytidæ* are little beetles which live under bark, and often prove very injurious to trees. They have four jointed tarsi, clubbed antennæ, and the head produced in front into a short muzzle. The females lay their eggs along the sides of galleries which they burrow out under the bark; the larvæ when hatched make tracks at right angles to the mother-galleries, and thus form curious and characteristic patterns.

The *Cerambycidæ*, or Longicorns have in most cases a characteristic appearance by which they may be easily recognised, though, owing to a great variety in their form and structure, the family as a whole is not easily defined. Thus the great length of the antennæ to which these beetles owe their name is not always a distinguishing feature, for in many genera the antennæ are much shorter than the body. The Longicorns resemble the Rhynchophora in having the first three joints of the tarsi furnished underneath with a brush-like covering of hairs, and the fourth joint very small and hidden between the lobes of the third; but they are distinguished from that tribe by the fact that the epimera of the prothorax do not meet, while the head, though sometimes produced into a short muzzle, is never prolonged in the form of a beak. The larvæ all have a strong family likeness, and are quite unlike those of the *Chrysomelidæ*. They are of a dirty-white or pale yellow colour, with a rather soft skin, and in general form most resemble the larvæ of *Buprestidæ*. These larvæ all live in the interior of plants; some feeding just under the bark, while the great majority bore tunnels in the woody tissue, or live exclusively in the pith. The males have as a rule longer antennæ than the females, and may often be distinguished by the larger size of the eyes, jaws, or prothorax, or the greater length of the legs. The females are provided with a flexible ovipositor, which can be protruded some distance beyond the end of the body. In the subfamily *Prioninæ* the anterior coxæ are


Hylotrupes bajulus, with larva (nat. size).

strongly transverse, and their sockets widely open behind, the sides of the prothorax are sharply edged, the palpi are never pointed at the end, and the front tibiæ are without a groove underneath. This subfamily is the least numerous in species, though many of these are distinguished for their great size. *Titanus giganteus*, a Brazilian species, sometimes measures over half a foot long, and is the largest of all known beetles, while the sawyer-beetle (*Macrodontia cervicornis*) and other species occurring in Tropical America, are not much smaller. Most of the *Prioninæ* are found in the warmer parts of the world. They are represented in Europe by *Prionus coriarius*, *Ergates faber*, and a few other forms. *P. coriarius* is the only species which occurs in England, and is not very common, being met with chiefly in oak-woods, where the larvæ live in the rotten trunks of trees. The *Ceram-*



Prionus coriarius, female ; and *Ergates faber*, male (nat. size).

bycinæ are widely distributed and include a very large number of species. They are as a rule narrower than the *Prioninæ*, and without sharp lateral edges to the prothorax, while the sockets of their front-legs are seldom strongly transverse and are often rounded and completely closed behind. Most of the species have a stridulating area on the mesonotum, and by this means are enabled to produce sounds. This subfamily includes a number of very remarkable mimetic forms, some with broadly expanded elytra, and black and tawny colours resembling *Lycidæ*, others with the elytra greatly reduced in size, and the shape of the body modified in imitation of various Hymenoptera. The metallic-coloured beetles of the group *Callichromides*, most of which are found in tropical countries, exhale a scent resembling otto of roses. In England this group is represented by the musk-beetle (*Aromia moschata*), figured on p. 154, a handsome insect of a golden-green or bronzy colour, which is met with on willow-trees. Amongst the European species of *Cerambycinæ*, the groups *Lepturides*, *Molorchides*, and *Clytides* are best represented. Some of the *Lepturides*, such as *Strangalia* and *Toxotus* are flower-frequenting

insects, others like *Rhagium* are found on the trunks of pine-trees. In the *Molorchides* the elytra are usually short or very narrow, and the abdomen slender and constricted at the base, so that many of the species have a resemblance to Hymenoptera. The European *Necydalis major* looks like a hornet, but in many of the tropical forms these resemblances are more pronounced. The *Clytides* are found on flowers, chiefly of the umbelliferous kind, and two or three species are among the prettiest of British beetles. Some of the *Clytides* and species of *Hylotrupes* and *Callidium* are occasionally met with in houses, being introduced in the wood in which the larvæ feed. The *Lamiinæ* are more numerous than the other Longicorns, and distinguished by having an oblique groove on the lower side of the front tibiæ, the last joint of the palpi usually pointed at the end, and the front of the head in most cases turned down vertically, or sometimes even inclined backwards, bringing the mouth close to the prosternum. The species of the genus *Lamia* are few in number and by no means typical of the subfamily; they are clumsy-looking, dull black insects, one of which (*Lamia textor*) is found on willow-trees and in osier-beds in some parts of Britain. In the genus *Acanthocinus* the antennæ attain their greatest length, being four times as long as the body in the male. *A. ædilis* is found in pine-woods in Scotland, and is met with occasionally in other parts of Great Britain and even in London, where it is sometimes introduced in timber. Amongst the exotic species of this subfamily, the harlequin-beetle (*Acrocinus longimanus*) is one of the most remarkable, being distinguished, not only by its curiously variegated colours, but also by the extraordinary length of the front legs in the male.


1. MUSK-BEETLE; 2, *Spondylis buprestoides* (nat. size).


Strangalia armata and larva (nat. size).


Toxotus meridianus, male and female (nat. size).

The *Bruchidæ* are a small but widely spread family of little beetles which are

found chiefly on leguminous plants. The larvæ live in the seeds, eating up all the internal parts and changing to pupæ within the outer shell. These beetles were at one time classed with the weevils, but are now generally recognised as being more nearly allied to the next family. They are illustrated on p. 1, where Fig. 1 is the pea-bruchus (*Bruchus pisi*); Fig. 2, the bean-bruchus (*B. rufimanus*); and Fig. 3, *B. granarius*, and larva; all of them being enlarged.



1, *Rhagium indagator*, with larva and pupa-case; 2, *Rhagium bifasciatum*. (Nat. size.)

The *Chrysomelidæ*, more commonly known as the Phytophaga—though this name is equally applicable to many other beetles—all live upon plants, feeding chiefly upon the foliage, while some also attack the flowers. They are almost as numerous as the weevils, and in their own way quite as destructive to vegetation. The family is divided into four sections. The Eupoda include those forms which most resemble the Longicorns. Many of the beetles belonging to this section have thickened hind-legs, but instead of being active jumpers, as might be suspected, they are really very slow and awkward in their movements. In the males of the genus *Sagra*, the hind-legs are enormously developed, the species of this genus being for that reason sometimes known as kangaroo-beetles. The *Donacinæ* live upon aquatic plants of various kinds; they have a bright metallic coloration, which in many species is veiled by a delicate covering of



Necydalis major (nat. size).

silky hairs, and their elytra are marked with rows of deep punctures. The larvæ feed under water upon the roots of the plants, and change to pupæ which are



1, *Lamia textor*; 2, Female of *A. ædilis*; 3. Male of *Acanthocinus ædilis*; 4, *Saperda carcharias*; 5, *S. populnea*. (All nat. size.)

enclosed in oval cocoons. In the beetles of the section Camptosomata, the body is short, the head vertical and deeply sunk in the prothorax, and the abdomen slightly curved, with its middle segments contracted; the antennæ are short and serrate or pectinate in the first subfamily, while in the second they are rather long and filiform. The larvæ move about surrounded by a sack-like case, from which the head and anterior part of the body are free. They retract themselves completely within the case and close up the opening when about to undergo their metamorphosis. The Cyclica comprise four subfamilies, of which the first, the *Eumolpinæ*, is almost entirely composed of exotic species, though one of the few species found in Europe (*Bromius vitis*) is only too well-known on account of the damage it inflicts on the leaves of the vine. With the *Chrysomelinæ* we come to the most typical forms belonging to the family.



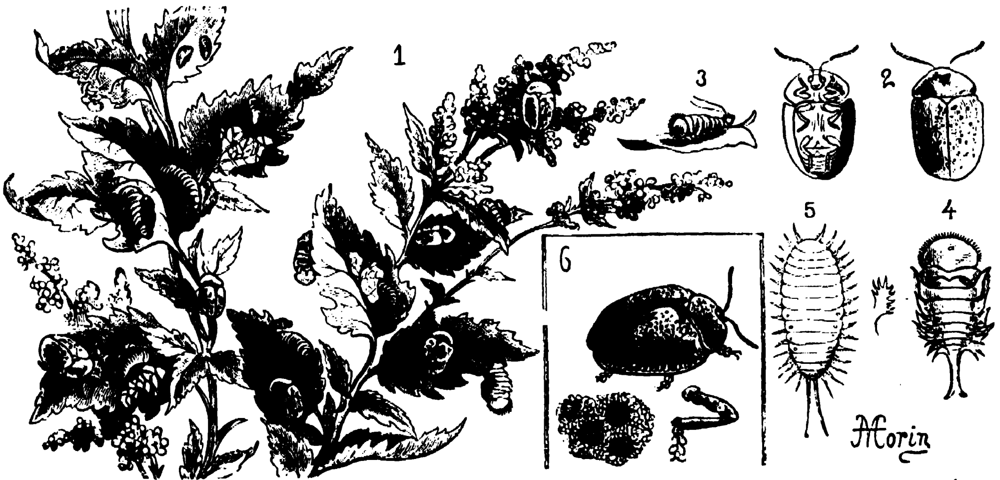
Donacia clavipes, with larva and pupa case (nat. size).

These beetles are distinguished by their oval and convex shapes, having in many cases a great resemblance to lady-birds (*Coccinellidæ*), while their colours are

nearly always brightly metallic or otherwise conspicuous. Some of the species are very gregarious in their habits. *Lina tremulæ* is often found in large numbers in all its stages on the leaves of aspen; the larvæ are somewhat like those of lady-birds, and have the habit of exuding a strong-smelling yellow liquid from the mouth and other parts of the body. The Colorado potato-beetle (*Leptinotarsa decemlineata*) is very destructive to the potato crops in North America. The *Galerucinæ* are poorly represented in Great Britain, while of the flea-beetles (*Halticinæ*) we have a large number of species, of which the best known are the turnip-flea (*Phyllotreta nemorum*), and other little jumping beetles which attack cruciferous plants. The larvæ of the *Halticinæ* usually mine in the tissues of the leaf underneath the epidermis; in this respect differing from the larvæ of most of the other *Chrysomelidæ*. The Cryptostomata are distinguished by having the front of the head inclined backwards so that the mouth is almost completely hidden. Two subfamilies are included in this section. The *Hispinæ* are remarkable for the sharp projecting spines with which many of the species are armed, while the *Cassidinæ* have the characteristic form to which they owe their name of tortoise-beetles. In Great Britain, the tortoise-beetles are represented by half a dozen or more species of the genus *Cassida*, one of which (*C. nebulosa*) in its different stages is illustrated in our figure.



COLORADO POTATO-BEETLE IN ALL ITS STAGES (nat. size).



LIFE-HISTORY OF THE TORTOISE-BEETLES (*Cassidinæ*).

1, *Cassida nebulosa*; 2, The beetle (enlarged); 3, The larva (nat. size); 4, The pupa, and 5, the larva (both enlarged); 6, *Desmonota variolosa*, with leg and portion of elytron enlarged.

A Brazilian species (*Desmonota variolosa*), remarkable for its deeply sculptured elytra and bright golden-green colour, is also shown in the same figure.

SECTION TRIMERA.

Two families, of which one only need be noticed here, are included in this section. The *Coccinellidæ*, or lady-birds are so familiar to everyone that it is quite unnecessary to describe their general appearance. They are resembled in shape by some other beetles, but in such cases the lady-birds may be distinguished by their three-jointed tarsi, clubbed antennæ, and the hatchet-shaped terminal joint of their palpi. These charming little insects have always been held in much respect, as the different names given to them testify, and it is well that it should be so. For while the species of a few genera (*Epilachna*, *Lasia*) are herbivorous in their habits, the great majority live—especially in the larval state—upon green-fly and plant-lice, and, by keeping these noxious insects in check, perform a useful service to man. The lady-birds are found in nearly all parts of the world, and over a



LADY-BIRDS.

1, *Micraspis duodecimpunctata* (nat. size and enlarged); 2, *Coccinella septempunctata*; 3, Larva (enlarged); 4, *C. impustulata*; 5, *C. bipunctata* and dark variety; 6, *Chilocorus bipustulatus*.

thousand different species are known. Among several species occurring in Britain the two commonest are, perhaps, the large seven-spotted *Coccinella septempuncta* and the small two-spotted *C. bipunctata*. The latter varies in colour to a great extent, so that between the typical form with red elytra marked with two black spots, and others in which the elytra are entirely black, one meets with almost every intermediate condition. The larvæ of these species may often be seen walking about on leaves that are infested with green-fly. They may be recognised by their slate-blue colour, marked with some yellow dots, and by the greed with which they devour the aphides. The larvæ, when about five or six weeks old, are ready to pupate. Fixing themselves by the tail-end to a leaf, they cast their skin, and the pupæ, resting upon the cast-off larval skin, remain attached to the leaf. The beetles emerge about eight days later, so that the whole course of development from the egg to the perfect insect is completed in less than a couple of months.

C. J. GAHAN.

CHAPTER V.

JOINTED ANIMALS,—*continued.*

INSECTS,—*concluded.*

Orders NEUROPTERA, ORTHOPTERA, RHYNCHOTA, etc.

Characters of the Neuroptera. THE Neuroptera form the last order of insects which undergo a complete metamorphosis in the course of their development. In this order it was formerly usual to include certain groups of insects, such as the dragon-flies, May-flies, white ants, etc., none of which pass through a period of prolonged inactivity, or pupal-stage, before reaching the perfect condition. But although it is largely a matter of convenience whether these groups be placed, as they are in this work, in the order Orthoptera, or arranged in a series of separate orders, no one, taking into consideration the great difference in their mode of development, would now think of associating them in the same order with the true Neuroptera. The adult insects of the present order have their mouth-organs, when fully developed, adapted to biting and grinding, and never formed for piercing or sucking; in which respect they differ from three of the other orders of the metabolous insects, namely, the Hymenoptera, Diptera, and Lepidoptera. From the Coleoptera they are easily distinguished by the structure of their fore-wings, which are never hard and horny like the wing-cases or elytra of the latter. Both pairs of wings are membranous, and usually traversed by numerous, more or less closely reticulating, veins; whence the name of Neuroptera given to the order. The hind-wings are often very similar to the fore-wings, but sometimes differ considerably in size and shape. In one section—the caddis-flies—they are capable of being folded like a fan, but in the other section (Planipennia) they always remain flat, and are spread horizontally or obliquely in repose.

CADDIS-FLIES,—Suborder **Trichoptera.**

The caddis-flies, forming the first of the two great divisions of the order, are in general appearance rather like some of the smaller kinds of moths; and since they differ a good deal from the typical Neuroptera, they are often treated as a distinct order. In their adult state they have two pairs of wings, in which the neuration is comparatively simple, with few transverse nervures. The wings are generally clothed with hairs, and the hind-wings usually shorter, broader, and less hairy than the front pair. When at rest, the hind-wings are folded fan-wise, with the fore-wings covering them over like a roof. The caddis-flies have a rather small head, which bears two long, tapering, and many-jointed antennæ. They have round and

prominent eyes, and usually also three ocelli, placed on the forehead. With the exception of the palpi, their mouth-organs are feebly developed. Their legs are long, and possess five-jointed tarsi; and the tibiæ are generally furnished with spurs, whose number and disposition are of considerable value in distinguishing the genera. These insects fly chiefly in the evening or at night, and, attracted by the light, frequently enter houses; some of the smaller species flying in swarms over water. The larvæ, with few exceptions, are aquatic in their habits; some being carnivorous, although most feed on vegetable matter. Found in streams, lakes, and ponds, or any piece of water in which plants grow, caddis-worms, as the



VARIOUS FORMS OF CASES MADE BY CADDIS-FLY LARVÆ.
1-5, Cases composed of sand and pebbles; 6, A case made of small snail-shells; 7-10, Cases made of different parts of plants.

larvæ are called, are well known to anglers, by whom they are frequently used as bait. The eggs from which they are hatched are laid sometimes in the water, or on aquatic plants or trees overhanging water. Females have occasionally been captured with a coating of dry mud on their abdomen, showing that they had gone to some muddy pool to lay their eggs. The cases, made out of all sorts of materials, with which many of the larvæ surround their bodies, have long been objects of interest to the naturalist. Some larvæ pick up bits of sticks and leaves, grains of sand, and fragments of shells, or whatever else comes handiest, and fasten them together in a rough sort of fashion; but many exercise a choice in the selection of materials, and exhibit great dexterity and neatness in piecing them together. The

shape of its dwelling, and the nature of the materials used, are often characteristic of the family, sometimes of the genus or species, to which a larva belongs. In the family *Phryganeidæ,* for example, the larvæ construct their cases with bits of leaves or twigs, cut into suitable lengths, and arranged side by side in such a manner as to form a spiral band passing many times around the case (see No. 7 in figure). The species of *Limnophilus* fashion their cases in various styles; the larvæ of *L. pellucidus* using entire leaves, so that the case may have a flattened form, wide in proportion to its depth. The cases made by *L. rhombicus* consist of bits of sticks or fibres placed transversely, with shells sometimes added; while those of *L. flavicornis* are often built almost entirely of the shells of different small molluscs, more especially those of *Planorbis.* What is still more remarkable about these cases is the fact that the case-worms do not necessarily select empty shells, but take those with living occupants as well, and fasten them all together around their backs. Grains of sand, of finer or coarser kind, are used by many larvæ in the construction of their cases; and the latter may be either cylindrical in form or slightly curved, or, as in the exotic genus *Helicopsyche,* they may, like snail-shells, have a distinct spiral curvature. The grubs of other species arrange bits of sticks transversely in four different directions, using longer pieces as they progress, so that the complete case is four-sided, with the sides gradually widening from one end to the other; and there is a type in which the four sides, instead of being straight, are carried round in a gentle spiral curve. The interior of each larval case is a tubular chamber, lined with silk, open at each end, and about wide enough to enable the larva to turn inside. At the fore-end, which is generally a little wider, the head, thorax, and the six legs of the larva may be seen projecting; whereas the hinder end is usually closed by a silken partition pierced with holes. The body of the naked larva is made up of a number of segments, of which the first three—carrying the legs—are, like the head, hard and of a brownish colour; while those that follow, about nine in number, are soft, white, and partly transparent. On the last segment are a pair of horny hooks, which enable the larva to grip tightly to its case. On the first abdominal segment three fleshy protuberances are often seen,—a longer one above and a shorter one on each side,—which appear to be used in enabling the larva to steady its body in the case, and to regulate its position with regard to the sides, so that the water necessary for breathing may pass freely in and out. The larva breathes by means of rows or tufts of soft white filaments—the tracheal gills—attached to the sides of all the abdominal segments except the first and last, and differing in arrangement in different species. Previously to entering the pupal stage, the larvæ of many species provide for their protection during that inactive and helpless period of their existence. They shut themselves up in their cases, some by closing the openings at each end with sieve-like plates of silk, which, while allowing free access to the water necessary for breathing, may serve to keep out their enemies; others by placing stones loosely over the openings, and so accomplishing the same purpose. There are a few larvæ, moreover, which, in their earlier days, make cases out of leaves, but add stones as they grow older, until just before pupation begins the case is entirely made of stones. Before the pupa is transformed into the perfect insect, it extricates itself from its case, and leads an active life, swimming

and running with agility. It then climbs up the stem of a plant to undergo its transformation. In some of the smaller species the pupa does not leave the water, but rises to the surface, and the fly emerges from the floating pupal skin.

Caddis-flies are divided into seven families, arranged in two groups chiefly distinguished by the number of joints in the maxillary palpi of the male insect. In the first section—Inæquipalpia—the maxillary palpi of the male are composed of two, three, or four joints, never five; thus differing from those of the female, in which the number of joints is always five. This section contains four families—the *Phryganeidæ*, *Limnophilidæ*, *Sericostomatidæ*, and *Hydroptilidæ*; the life-



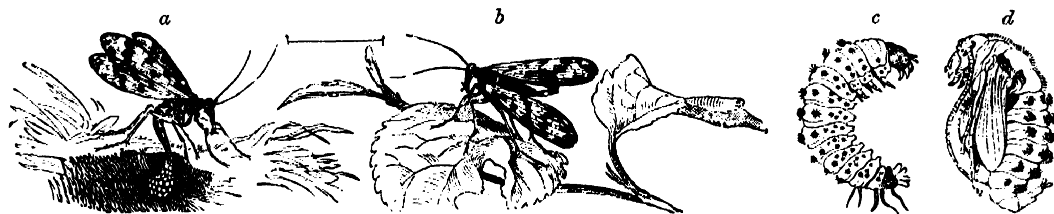
LIFE-HISTORY OF THE CADDIS-FLY.
1, Larva; 2, Pupa; 3, Larva in its case; 4, Perfect insect.

history of a species of the typical genus (*Limnophilus*) being depicted in our illustration. The second section—Æquipalpa—is characterised by the fact that the maxillary palpi of the male are five-jointed like those of the female; it includes the families *Leptoceridæ*, *Hydropsychidæ*, and *Rhyacophilidæ*.

Flat-Winged Group,—Suborder **Planipennia**.

The members of this group are distinguished from the last by having both pairs of wings formed nearly alike, and usually provided with a closely reticulated system of nervures, with numerous transverse branches. The wings—which are incapable of being folded up—are for the most part naked; and, when at rest, are turned back in a slanting position against the sides of the body. The mouth-organs are well-developed, the mandibles in some cases attaining extraordinary proportions. The first family is that of the scorpion-flies (*Panorpidæ*), which have a slender body, and the head turned downwards and prolonged in the form of a beak, resulting from the elongation of the clypeus in front, and of the lower lip and maxillæ behind. The mandibles are rather short and narrow; the maxillæ, which are fused with the mentum, have five-jointed palpi; and the narrow lower lip is bifid at the extremity, with three-jointed palpi. The antennæ are setiform, and inserted between the rather prominent eyes, and below the ocelli, which are usually distinct. The prothorax is short and collar-like; and the wings of these

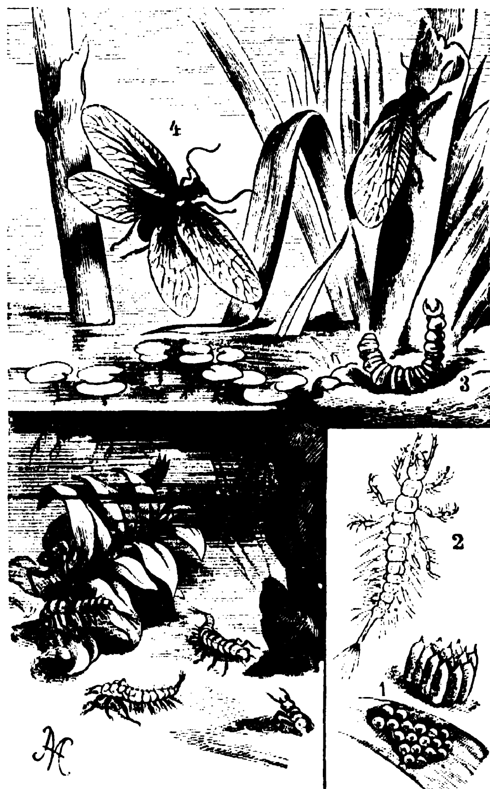
insects are less closely reticulated, and have fewer transverse nervures than those of the other groups. The common scorpion-fly (*Panorpa communis*), which may be taken as the type of the family, is a shiny black insect about half an inch or more in length, with long, transparent, spotted wings, and a yellow beak and legs. The three last body-segments of the male are narrow, and can be curved like a tail, and



COMMON SCORPION-FLY.
a, Female depositing her eggs; *b*, Male; *c*, Larva; *d*, Pupa.

have a reddish colour; and the last carries a pair of pincer-like claws. It is from this circumstance that the insect has received its name, though it does not possess a sting like a scorpion.

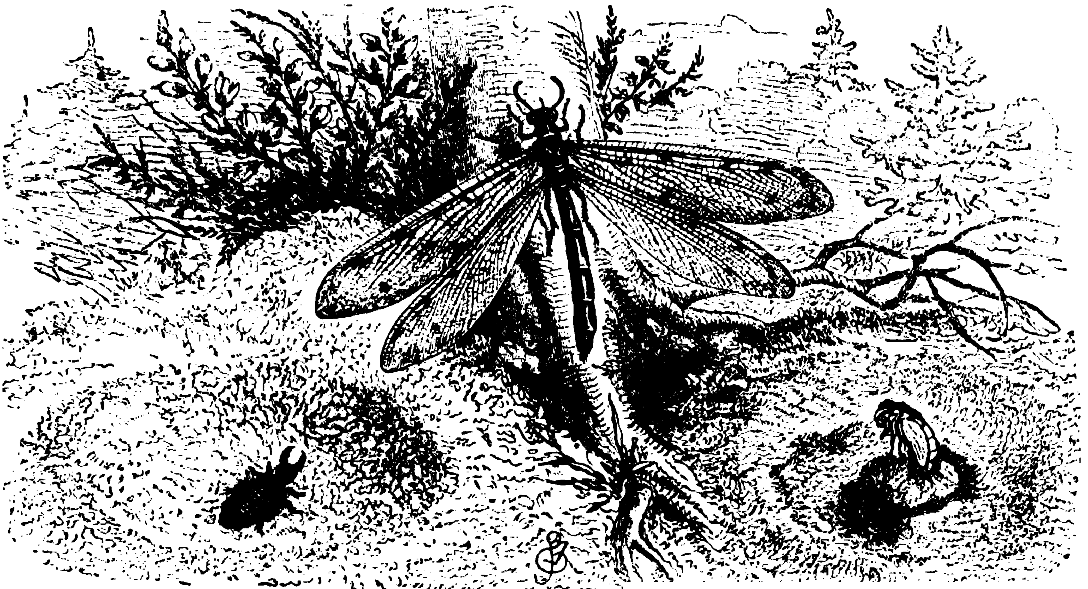
In the snake-flies and alder-flies (*Sialidæ*), forming the second family, the head is comparatively large, and often inclined in front, but never elongated in the form of a beak. The antennæ are bristle-like, and not so long as the body; the prothorax being strongly developed. The camel or snake-flies (*Rhaphidia*) have the head long and narrow behind, and freely articulated with the long and narrow prothorax. The latter can also move freely at its articulation with the segment which follows; and this explains how the prothorax is raised, and the head bent forward in the characteristic attitude which these insects adopt when about to seize their prey, which consists usually of various small insects.



LIFE-HISTORY OF THE ALDER-FLY.
1, Eggs; 2, Larva; 3, Pupa; 4, Imago.

The alder-fly, or May-fly (*Sialis lutaria*), is at first sight rather like a caddis-fly, but has a stouter body, and may be distinguished by its more completely developed mouth-organs, as well as by the different structure of its wings. It emerges from the pupa about May or June. The winged insects fly slowly and heavily, and are to be met with about trees and shrubs, or walls and palings, at no great distance from water. The female, which is somewhat larger than the male, lays her eggs in patches on a plant or other object in the vicinity of water. There may be

several hundred eggs packed closely together in a single cluster; they stand upright, being cylindrical in form, with rounded ends, and each terminating above in a little white projection. The larvæ hatch in a few weeks, and then find their way into water, where they creep on the mud in search of the aquatic creatures on which they feed. When full-grown, they are about an inch long, with a body tapering slightly towards the head, and, more gradually, towards the long and narrow tail. The head and three thoracic rings are horny, the rest of the body having a softer integument. The larva, which has strong legs and can walk well, breathes by means of tracheal gills, having the form of jointed appendages attached in pairs to the sides of the first seven abdominal segments. When the time for pupation arrives, generally about May or June, the larva leaves the water and seeks a place to bury itself in the earth. Having excavated a little cell, it throws off the larval skin and becomes a pupa, which has the legs and wings free from



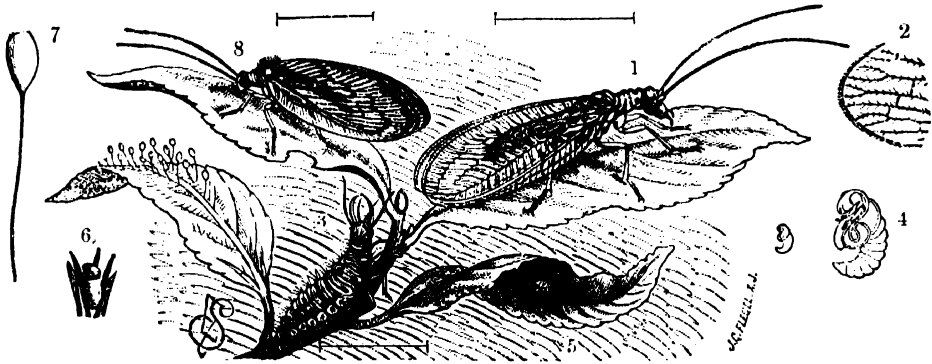
LIFE-HISTORY OF THE COMMON ANT-LION.
a, Imago ; *b*, Larva ; *c*, Pupa (nat. size).

the body, but enclosed in special sheaths. After a few weeks longer it is transformed into the perfect insect.

The lace-wing flies, ant-lions, mantis-flies, and some other families, have been associated in a third group of Planipennia, to which the name Megaloptera is given. In all, the wings are relatively large and closely reticulated; the prothorax being variable in size and form, and the joints of the tarsi not dilated. The mantis-flies (*Mantispidæ*) take their name from the shape of the fore-legs, and their position near the front end of the long prothorax; in which respect they resemble the mantis or praying insect. One species is common in South Europe. The larvæ live parasitically in the nests of spiders and tree-wasps; and while they are at first free and active, they afterwards become almost legless, like those of certain beetles. The allied family *Nemopteridæ* is mainly characteristic of the countries around

the Mediterranean Sea. These insects have elongated and narrow, or almost linear, hind-wings, often widened out a little before the tip. The ant-lions (*Myrmeleontidæ*) may be recognised by their clubbed antennæ, and their long and closely reticulated wings, rounded off to an obtuse point at the extremity.

Of the European species the common ant-lion (*Myrmeleon formicarius*) is one of the best known. It lives in pine-woods. The winged insect, which may be seen in July and September, rests during the day clinging to a plant, with its wings spread like a roof over the hind-part of its body. At sunset it becomes active, and executes a slow flight in its search after food or a mate. The larva, to which the name ant-lion properly belongs, has the habit of making pitfalls to entrap its prey. It is somewhat oval in the shape of its hind-body, and has a narrow prothorax resembling a neck, and a rather big head, provided with a pair of long, curved, and sharply pointed mandibles, each of which has three teeth on the inner side. Its body is arched up in the middle, and has wart-like protuberances, thickly covered with hairs, at the sides. When about to make a pit,



LACE-WING FLIES.
1, *Chrysopa vulgaris*; 2, The tip of its wing; 3, Larva; 4, Pupa; 5, 6, Cocoon; 7, Egg; 8, *Hemerobius hirtus*.

it selects a dry and sandy spot, and begins by tracing out a circular furrow to mark its outer limit. Placing itself inside the circle, it buries its abdomen in the sand, and then proceeds with the work of excavation. With one of its fore-legs it shovels the sand on to its large flat head, to which it then gives a sudden jerk, and sends the sand out over the border. It repeats this process, walking backwards and maintaining a spiral course all the while, until finally it reaches the centre of the cavity. Sometimes. however, instead of continuing to work altogether in one direction, it turns round and works the opposite way, thus giving relief to the leg which had previously been employed. And, as the sand is always taken from the inner side, it is the leg on that side which is always used as a shovel. The pit, when completed, is shaped like the mouth of a funnel, being wide above and gradually narrowed to the bottom. Its size is adapted to the size of the larva, which when full grown makes a pit about two inches deep, and three inches wide at the top. Buried in the sand at the bottom, with only its antennæ and the tips of its mandibles projecting, the ant-lion waits until an ant or some other creature falls down the loose sides of the pit, when it is immediately seized with the pincer-like jaws, and retained until all the juices of its body have been sucked out, and nothing left but the dry and shrivelled skin. The latter is cast outside the pit, and the

larva again lies in wait. If by chance the victim should escape the first onslaught, and endeavour to scramble up the sides of the pit, its attempt is soon frustrated, for the ant-lion throws up sand with its head, causing the victim to tumble once more to the bottom.

The lace-wings flies (*Hemerobiidæ* and *Chrysopidæ*), are smaller and more delicate insects than the ant-lions, and have setiform antennæ. The golden-eyed fly (*Chrysopa vulgaris*), figured on p. 165, may be taken as a typical species. It is slender, with long and richly-veined wings of a tender green colour, as is also the body. Its antennæ are long and tapering, and its prominent eyes shine like hemispheres of gold. The larvæ of the lace-wings are not unlike the ant-lion, although somewhat longer and narrower in proportion to the size of their bodies, and less hairy. Their mandibles, moreover, have no teeth on the inner side. In their carnivorous habits they resemble ant-lions, but instead of making pits and remaining stationary they rove about in search of their prey, which consists of the different kinds of green-fly and plant-lice.

Order Orthoptera.

This order being taken to include, not only the true Orthoptera, but various other groups formerly placed in the Neuroptera, and hence known as Pseudoneuroptera, it is necessary in defining the group to mention only such characters as are common to the whole of these insects. None of the members of the group undergo a distinct metamorphosis; the development from the larval to the adult condition taking place by a succession of changes, and the perfect insects being distinguishable from advanced larvæ by little more than the possession of complete wings. The wings are, however, in some cases confined to one sex, while in others they are altogether wanting in both sexes. The mouth-organs, when not reduced to a functionless condition, are adapted to biting; the lower lip (labium) is nearly always divided in the middle at its free end, and each of the two halves often subdivided into a pair of lobes. On the floor of the mouth, concealed by the labium, there is, as a rule, a membranous or more or less horny structure, known as the tongue (lingua), or hypopharynx, which is free from the labium in its anterior part. Though poor in the number of species, as compared with some other orders, the Orthoptera contain many of the most interesting forms of insect life; some, like the leaf and stick-insects, remarkable for their size and the variety of their protective disguises, others, as the white-ants, for the wonderful development of their social habits. The day-flies are noted for the shortness of their lives, the dragon-flies for their beauty; while many other forms are well known from some particular feature or habit. In past epochs of the earth's history Orthoptera were well represented, their remains being found in rocks of various ages extending back to Palæozoic times. The oldest reputed insect is known by the impression of an orthopterous wing (*Palæoblattina*), from the Silurian sandstone of Calvados in France. There is some doubt as to which group of the order the insect belonged, and even as to whether the impression owed its origin to an insect at all. However this may be, traces of undoubted Orthoptera, as well as of Neuroptera, are met with in rocks of Devonian and Carboniferous ages. The Orthoptera of the latter period included

numerous cockroaches (*Blattidæ*), together with stick-insects, ephemerids, and dragon-flies, some of which greatly exceed in size any existing form. One of the dragon-flies (*Meganeura monyi*), was 13 inches in the length of its body, and each of its wings was quite a foot long.

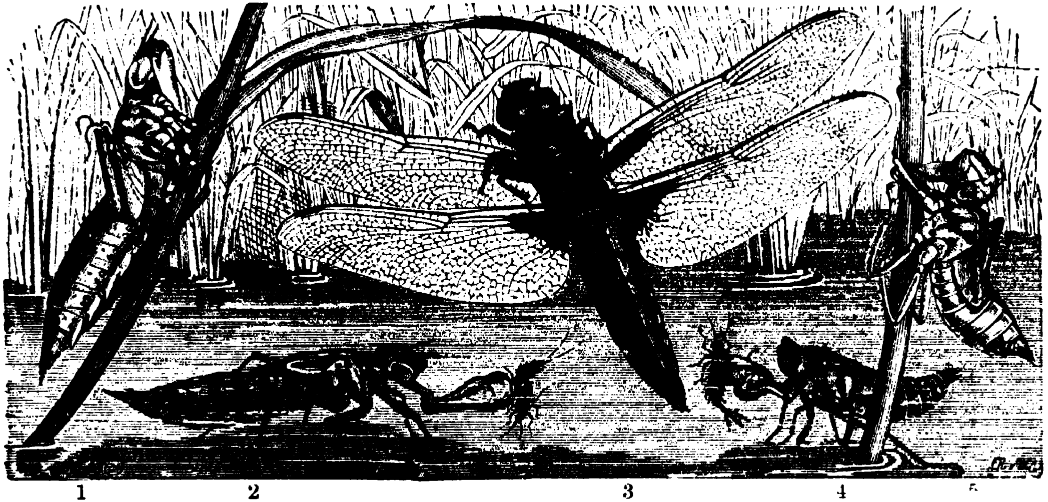
The Pseudoneuroptera are distinguished from the Neuroptera by the absence of a pupal stage. While agreeing in this respect with the typical Orthoptera, these insects differ by certain characters not generally considered of the first importance. Both pairs of wings in this group are thin and membranous, resembling one another in structure, and the hind-wings do not fold up; whereas in the true Orthoptera the fore-wings are usually thicker and harder than the hind-wings, and the latter are capable of being folded like a fan.

Dragon-Flies.

The first group is that of the dragon-flies (Odonata), the general appearance of which is too well known to need description. All have a large head, the sides of which are covered almost entirely by the two big, glassy-looking, compound eyes, while on its crown are two or three small simple ocelli. Each of the short and bristle-like antennæ has a stouter basal portion by which it is inserted on the forehead. The mouth faces downwards, and has a large semicircular lip (labrum) in front; the jaws being strong, horny, and well provided with teeth. The maxillæ are without palpi, but their narrow and palp-like outer lobe is often regarded as the real palp. Succeeding the jaws behind is the lower lip (labium), which at its free end is usually slightly cleft in the middle, while its palpi take the form of two dilated and often two-jointed lateral lobes; these lobes sometimes overlapping one another in front to hide the free end of the lip. The thick and cylindrical thorax is followed by a long slender abdomen, which usually carries at the end two leaf-like or pincer-like appendages. When looked at from the side, the two hinder segments of the thorax appear oblique, with the wings set rather far back above, and the legs pushed forward below. The wings are long, transparent, and traversed by a rich network of veins. The legs are often spiny, and their tarsi are always three-jointed. The position of the accessory organs of the male on the under side of the second abdominal ring is a feature distinguishing dragon-flies from other insects.

The female dragon-fly deposits her eggs in such a position that the larvæ, when hatched, find themselves either in their natural element, the water, or very close to it. In some species the female, accompanied by the male, goes under the water to lay her eggs; others drop them into the water; while in many species the female makes incisions in some aquatic plant and there deposits her eggs. The larvæ are even more fiercely carnivorous than the adult, and are distinguished from all other aquatic larvæ by the possession of a peculiar structure fixed under the head, known as the mask. In their mode of respiration dragon-fly larvæ are also peculiar, some being provided with external tracheal gills—in the form of three leaflets placed near the tail-end—which serve also to assist in locomotion, while others breathe by means of gills of an exceptional character. The latter are situated in the hinder part of the intestine and consist of six longitudinal bands in its walls, crossed by several transverse folds, supplied with numerous fine branches from the tracheal trunks. Water can be sucked in at the opening, guarded by five valves at the hind end of the body, and

when it becomes vitiated can be squirted out again either gently or with considerable force. When it is suddenly and violently expelled, it serves to propel the insect forwards at a rapid rate. The larvæ live about ten or twelve months, during which time they undergo several moults; rudiments of wings appearing some time before the final transformation. When this is about to take place, the larva leaves the water by climbing the stem of a plant, or to some other dry spot. As the time approaches, its eyes, which were before dull and opaque, become bright and transparent. Its skin dries up, and soon begins to crack along the middle of the thorax; the thorax appears through the cleft, and swelling up causes it to extend; the head is next disengaged, and the legs are then drawn out of their sheath. The insect now throws its head farther and farther back, and by this means gradually frees the hinder part of its body, with the exception of the last few segments which still remain enclosed in the larval skin. After a while, it suddenly bends its body forwards, grasps the



LIFE-HISTORY OF DRAGON-FLIES.

1, Larval skin of a dragon-fly; 2, Larva with its mask exserted; 3, *Libellula depressa*; 4, Advanced larva of a libellula; 5, The same about to undergo its final transformation.

sides of the sheath with its legs, and, doubling up its abdomen, finally extricates the rest of its body.

Dragon-flies are divided into three families, of which the first two have more in common with one another than with the third. The *Libellulidæ* are distinguished by their comparatively stout bodies; by the size of their eyes, which cover almost all the sides of the head, and very nearly meet on its crown; and by the structure of their lower lip, in which the median terminal piece is short and slightly divided at the end, while the very broad palps spread out and overlap it in front. The last character is useful in distinguishing the *Libellulidæ* from the next family, which in many respects they resemble. Their larvæ breathe by means of internal gills, and have a mask which is hollowed out on the inner side, and somewhat resembles a helmet. Members of this family are found in most parts of the world, and about twenty species occur in Europe. The *Æschnidæ* have eyes even larger than those of the *Libellulidæ*. The end piece (ligula)

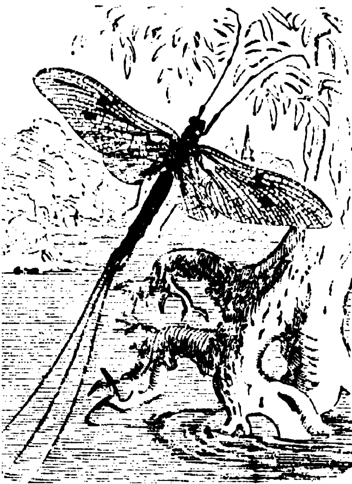
of their lower lip is not divided in front, and not exceeded in length by the palpi; while each of the latter is armed with a strong tooth or spine. The abdomen is long, narrow, and cylindrical. Their larvæ are more elongate, and have bigger eyes than those of the last family. The flat mask has the palpi narrow, and armed with a movable hook at the tip. Like the larvæ of the *Libellulidæ* they are provided with intestinal gills. Some of the largest dragon-flies belong to this family.

The *Agrionidæ* form a family of slender-bodied dragon-flies, which have both pairs of wings shaped nearly alike. They are further distinguished from the other two families by the shape of the head, the smaller size of the eyes, and the structure of the lower lip. The head has a projection at each side, at the end of which is placed one of the two hemispherical eyes; and on the wide space, lying between the compound eyes, there are three ocelli arranged in a triangle. The lower lip consists at its free end of three parts of nearly equal length; the median piece (ligula) being notched in the middle, while the two palpi consist of two joints, of which the first is large and terminates in an inwardly curved spine, whereas the second is small and articulated with the first, outside the base of its spine. The larvæ may be known by the three leaf-like tracheal gills at the end of their body, which are wanting or inconspicuous in those of the other families. This family contains many of the most brilliantly and variously coloured dragon-flies; the sexes of the same species often differing in coloration. Some of the exotic species attain a great length, but this is brought about by the elongation of their slender abdomen without a corresponding increase in the proportions of the other parts of the body.

May-Flies.

The day-flies, or May-flies (*Ephemeridæ*), constituting the second group of the Pseudoneuroptera, are comprised in a single family. They have soft and fragile bodies, with a long ten-jointed abdomen, bearing at the extremity two or three long, bristle-like, and many-jointed tails. The hind-wings are sometimes wanting, and, when present, are always much smaller than the front pair, the latter being usually three-sided, with the corners rounded off. Three ocelli, in addition to the two large compound eyes, are borne upon the head; and the antennæ are short, and composed of two stout basal joints, followed by a slender, many-jointed bristle. In the adult the mouth-organs are never well developed, but remain small and soft. The jaws have no function to perform, as the perfect insects do not eat, but devote entirely to other pursuits the short span of life remaining to them. The common notion that the life of the May-flies in the winged state lasts but a single day is sometimes, but not generally, true, many being able to live several days, provided the atmosphere be not too dry. There are some, however, which do not live for even the proverbial day, but emerge one evening, only to perish before the sun again appears. There is less truth in the supposition that these insects appear only in May; May-flies of one species or another being seen on fine days throughout the summer and autumn. They are to be found in the neighbourhood of rivers and lakes, some flying only by night, and others during the cooler hours of sunlight, or on favourable evenings until a little after sunset. During the heat of the day they seek repose, with their wings raised vertically. If the day be cold and raw, they seldom fly, but remain under shelter. In fine

weather, however, they may sometimes be seen assembled together in swarms about sundown, and engaged in their pastimes, which are continued till some time after sunset. The peculiar up-and-down movement, which marks the flight of some species, has been often observed; and the mazy dance of the May-flies has been described by more than one author. In these dancing assemblies the male insects always greatly outnumber those of the other sex. The larvæ of the *Ephemeridæ* live in water; a few kinds are carnivorous, but most feed upon the minute vegetation scattered through the mud or covering stones, and the larger aquatic plants. Many remain concealed in the banks or under stones, while others rove among water-weeds, and swim with celerity. The larvæ of some genera are found only in large rivers. The eggs are, in some cases, deposited at the surface of the water, and then sink to the bottom; but in others the female creeps into the water to lay her eggs in patches on the under side of stones. The eggs are exceedingly numerous, and vary in shape according to the genus. The larvæ cast their skin several times; they are at first without special organs of respiration, but when they are about eight or ten days old tracheal gills begin to appear and ultimately develop into forms, which vary somewhat in the different genera. The gills are attached in pairs to the sides of some, or all, of the first seven segments of the abdomen, in some species standing out straight from the sides, and in others turned over the back. The mouth-organs of the larvæ are better developed than in the adult, the mandibles being nearly always strong and toothed, and sometimes giving off a tusk-like process in front of the head. At their transformation most May-flies do not change directly from the larval form into the imago, but first pass through a stage, known as the subimago, in which they have their wings expanded, and breathe through the spiracles like the perfect insect. In this form they are distinguished by the dulness of their integument, the shortness of the fore-legs and tail-bristles, and the less prominent and duller eyes. The subimago emerges from the larval skin at the surface of the water, and, after standing awhile upon the water, flies to a more convenient resting-place. At the next moult, which soon follows, the perfect insect makes



MALE OF COMMON MAY-FLY, *Ephemera vulgata* (nat. size).



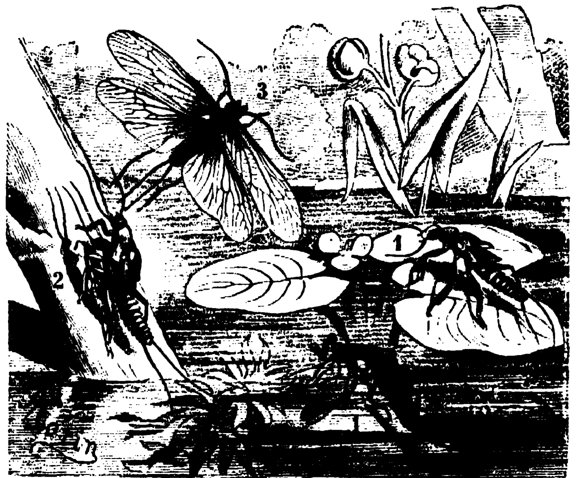
A MAY-FLY AT ITS FINAL MOULT, WITH THE IMAGO ESCAPING FROM THE SKIN OF THE SUBIMAGO. THE LARVA BELOW.

its appearance. The emergence of May-flies takes place at different periods during summer and autumn, and that of any one species may last for several days in succession. At this time they sometimes appear in countless numbers, as thick in the air as snowflakes, and at the end of their brief existence leave their dead bodies to cover the ground, or float in masses down the stream.

Nearly fifty species of *Ephemeridæ* are found in the British Islands. Two of the commonest (*Ephemera vulgata* and *E. danica*) are, in the subimago stage, known to anglers as "green drake," and "grey drake." They are four-winged species, with a body from one-half to three-quarters of an inch in length, and furnished at the end with three very long tails. The fore-legs are extremely long, especially in the males, which sex is distinguished also by the much larger size of its eyes. The larvæ of *E. vulgata* burrow in the mud, or hide under stones, in ponds and sluggish streams. They have rather long antennæ, and the tusks of their mandibles project a good way, and cross one another in front of the head. They have six pairs of tracheal gills, which are turned up over the back, each gill consisting of two narrow blades, united at the base, and fringed with hairs along each side. The final transformations of the larvæ occur about the end of May, or early in June, at which time, on a fine evening, the winged insects may sometimes be seen in hundreds, dancing in the air.

Stone-Flies.

The stone-flies (*Perlidæ*), forming the last group of Pseudoneuroptera with aquatic larvæ, are narrow, elongated insects of a flattened form, with a good-sized head, rather long, many-jointed antennæ, and four not very closely reticulated wings, which shut horizontally over the body when at rest. The abdomen usually carries two long, multiarticulated styles at the extremity. The mouth-organs are weakly developed in the adult insects; the mandibles and maxillæ are membranous; the maxillary palpi long, with slender terminal joints, and the labial palpi three-jointed. The thorax is square or oblong, with its three segments almost equally developed. The tarsi are three-jointed, and have their claws separated by a bilobed pad. The species of this family are not numerous, though some are almost worldwide in their distribution. The adults appear about the same time as dragon-flies and alder-flies, and frequent nearly the same places. Though they have large enough wings, they fly heavily, and not for any considerable distance at a stretch, and are generally most active in the evening. The female fastens her eggs loosely together, and drops them in masses as she flies over water. The larvæ are mostly found in rapid streams, where they keep under stones, or among broken pieces of wood, and live by preying actively upon the



COMMON STONE-FLY (*Perla bicaudata*).
1, Larva; 2, The fly escaping from the larval skin; 3, The perfect insect.

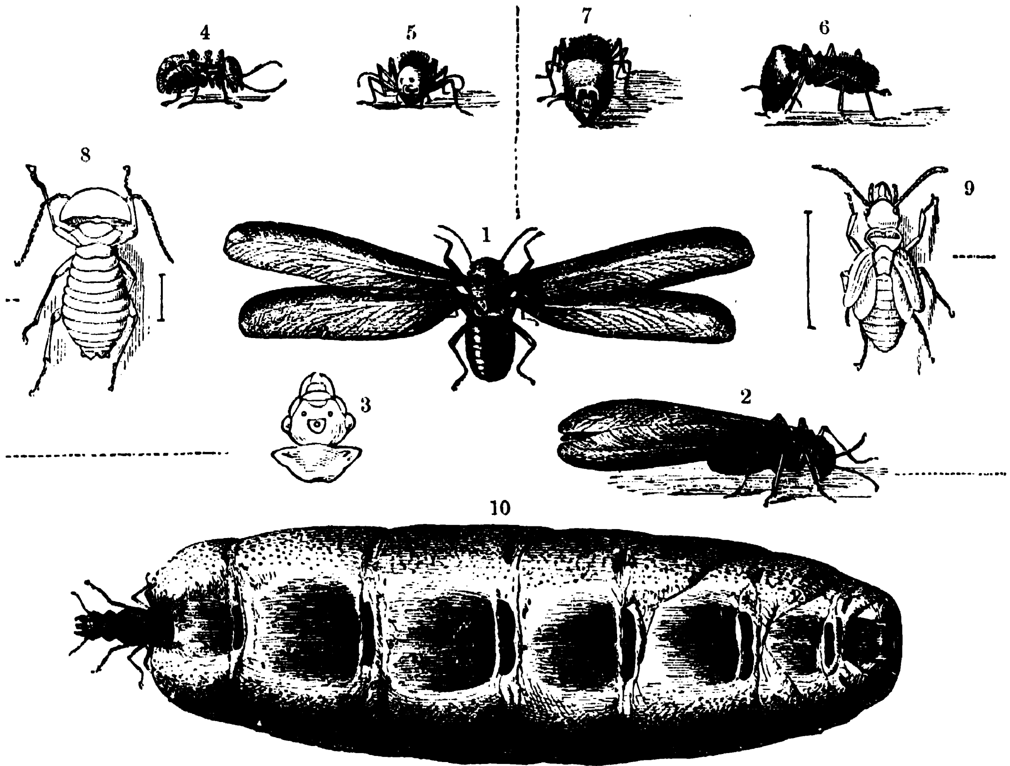
weaker creatures inhabiting the same waters. They have strongly developed jaws, and rather long palpi. They breathe by means of tracheal gills, in the form of tufts of filaments, attached to the bases of the legs and the sides of the integument which joins the three thoracic and the first abdominal rings to one another. The two filamentous tails may have a pair of tracheal tufts at their base. In later stages of their life the larvæ exhibit rudiments of wings. When the time for its transformation arrives, the full-grown larva, or nymph, leaves the water by climbing the stem of a plant, or crawling some distance up the bank until it finds a dry stone on which to stand, when the emergence of the imago takes place in the usual way, preceded first by a splitting of the larval skin along the middle of the thorax. When the insect is free, its wings dry rapidly, and it is soon ready to fly.

A fact of importance, first noticed in the *Perlidæ*, though it also occurs in some other groups, is that the tracheal gills are retained by the perfect insects, where they are attached in the same places as in the larva, but much reduced in size, and probably, in most cases, functionless. As an example of the *Perlidæ*, one of the best known British species, *Perla bicaudata*, is figured on p. 171.

Termites, or White Ants. The termites, or white ants (*Termitidæ*), differ considerably in one respect from all the other groups of Pseudoneuroptera. They live in societies which are of a highly organised and complex nature and most resemble those met with among insects of the highest type, such as bees and ants. This is, however, the only direction in which the termites diverge to any extent from the rest of the Orthoptera; for, like all these, they pass from the larval to the adult state by a series of gradual changes; while, in the structure of their bodies, they show an affinity with some of the lowest groups of the order. In the termites the head is free and distinct, with the antennæ composed of a number of small bead-like joints, and rather short. The perfect insects have compound eyes, and, as a rule, two ocelli; but the wingless individuals are generally without eyes of any kind. The mouth-parts, which are constructed on a clearly orthopterous plan, are not very unlike those of a cockroach, and consist of a distinct upper lip (labrum), two strong horny mandibles, a pair of two-lobed maxillæ with five-jointed palpi, and a lower lip (labium), divided at the end into four lobes, and bearing three-jointed palpi. In the thorax the first segment is well developed, and its dorsal plate, or pronotum, is rather broad and flat; the other two segments being less strongly developed, though in the winged insects attaining a fair size. Both pairs of wings are much alike; they are long, narrow, not very closely veined, each wing being marked by a transverse suture at a short distance from the base; and in a state of rest they are laid flat over the back. The legs are slender, and well fitted for running, and their tarsi are four-jointed. The abdomen has a slightly elongated or oval form, and carries two very short appendages—the cerci—near its extremity.

The common habitation of a society of white ants is known as a nest; and in each nest, which is divided into a number of cells or chambers communicating with one another, there may be found several different kinds of individuals in addition to the larvæ. Some are provided with wings, or with the rudiments thereof, and are distinguished also by having eyes. These are the sexually developed males and females, which are capable of reproducing their kind; though this function is, as a rule, carried on by a single couple in each nest. The king and queen—as this

couple are named—are lodged in a large cell near the middle of the nest, and may be recognised by their large size, and the fact that they retain but small stumps of the wings which they once possessed. The royal cell is larger than the others, and has thicker walls; while the passages leading into it are too small to afford the occupants a means of escape, though large enough to admit the workers, which come and go, some to bring food to the royal pair, others to carry away the eggs laid by the queen. At this time the abdomen of the queen, owing to the number of eggs it contains, is swollen to an enormous size. "She lies there," writes Drummond, in reference to one of the African species, "a large, loathsome,



WHITE ANTS AND THEIR DEVELOPMENT.

1, Male of *Termes dirus*; 2, The same, seen from the side; 3, The head, enlarged; 4, Worker; 5, The same. front view; 6, 7, Soldier, side and front view; 8, Worker (much enlarged); 9, Nymph; 10, Queen.

cylindrical package, 2 or 3 inches long, in shape like a sausage, and as white as a bolster." Her eggs are discharged at a rapid rate, amounting in a single day to several thousands, and the process is continued with the same activity for months in succession. Both workers and soldiers are wingless members of the community, and, in the majority of species, have no eyes. The workers have small and rounded heads, with short mandibles, and well-developed maxillæ and palpi; whereas the soldiers are easily recognised by their big, square, or oblong heads, and long mandibles. The workers are the most numerous class, and have many duties to perform in the way of building, tunnelling, and providing food for the young larvæ and for the king and queen. The soldiers look after the protection of the workers, and act generally in defence of the community. In one genus

there are no true mandibulate soldiers; but there is instead a class of individuals, known as "nasuti," from the fact that their pear-shaped heads are prolonged in front in the form of a beak The exact part which the nasuti play is not yet clearly known; but, like the soldiers of other species, these individuals appear at the first sign of danger, and shake their head and palpi in a most menacing way. The eggs of the queen termite are, as mentioned, carried away by bodies of workers, and placed in special chambers, or nurseries. When the young larvæ are hatched, they are at first indistinguishable from one another, and are little blind creatures, with soft and pale integument; and it is only after the first or second moult, that they begin to show those differences which subsequently distinguish the larvæ of the various classes. They are fed with a special kind of food, consisting of comminuted dead wood, mixed with saliva, which certain of the workers prepare for them. By varying the quantity and quality of the food supplied, the termites appear able to arrest or deviate the development of larvæ that would, in the ordinary course, become perfect insects or, in other words, they can produce workers and soldiers from larvæ which, if fed upon a different diet, might develop into winged insects fitted to become kings and queens. And it has been shown that neither the soldiers nor the workers of the termites belong to one particular sex only, as is the case with the neuters of bees and ants, but that individuals of both sexes, in an imperfect sexual condition are comprised in each class. The winged insects into which many of the larvæ develop are most abundant at certain periods of the year, especially after rains; they do not remain long in the nest, but, after a few days at the most, make their way out, or are led out by the workers, and shortly afterwards take flight. They may often be seen flying in swarms, and at night sometimes enter houses, being attracted by the light. Many are devoured by birds, which seize them as they leave the nest. When they have finished their flight, and alight on the ground, they shed their wings, which easily snap off at the line of suture near the base. If a couple, chancing to be near a termite burrow, are found by some workers, they are brought in, a royal cell is prepared for them, and, as king and queen, they become the parents of a new colony. Some larvæ develop into individuals, which, although fitted to perform the functions of perfect insects, never possess complete wings, but are provided at most with wing-pads, or rudiments of wings. These individuals, which somewhat resemble the nymphs of the perfect insects, are known as substitution kings and queens, and take the place of true royal couples, when from any cause the latter are not to be found.

The food of white ants consists ordinarily of decaying wood, or similar vegetable matter, which, when it has passed in a half-digested state through their bodies, is eaten again. These insects have also the habit of devouring their dead, which makes it possible to destroy a whole colony by placing a little arsenic or mercuric chloride in their food; for the few that die through first partaking of the poison are eaten by others, which in their turn are also devoured, and so the poison is spread through the entire population. About two hundred species of termites have been described; and these inhabit chiefly the tropical and subtropical parts of the world, although two small species are found in the south of Europe. Some species live in the hollows they have eaten out in the interior of the

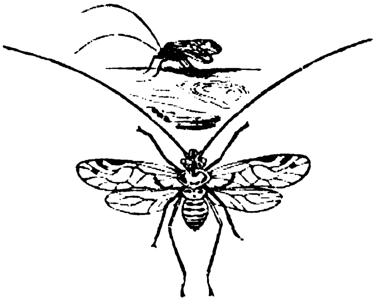
trunks and branches of trees, or in timber. They line the galleries they make, which are often so close together as to be separated only by a thin wall, the wood in the interior being almost all eaten away. A few make openings to the exterior, and form nests around the branches of trees; these nests being sometimes as large as a sugar-barrel, though the size varies considerably. The nests of most species are usually placed entirely below the level of the ground, and often lie beneath mounds of earth raised above the surface. Some of the larger African species, such as *Termes bellicosus*, build mounds of earth, frequently reaching a height of 12 or 14 feet. These mounds, which may stand singly, or in groups of varying size, are divided inside into chambers and galleries communicating with one another and with the nests and galleries underground. The nests of this kind, which consist almost entirely of clay, become in time quite hard and solid, and are much more durable than those which are composed of particles of dead wood pasted together with sticky saliva or with excrementitious matter. From the central nests termites construct underground galleries or tunnels leading in different directions, and sometimes reaching hundreds of feet in length. When it is necessary for the workers to go above ground in search of food, they protect themselves by building covered ways leading to the object they desire. Their tunnels sometimes lead to the interior of houses, and when once termites gain admittance in this way there is scarcely any limit to the mischief which may result from their operations. The wooden pillars that support the roof, the wood-work of the roof itself, and even articles of furniture, may be destroyed before the inhabitants become aware of what is taking place. For in tunnelling through wood termites take care to leave the outer shell intact; and what appears on the outside to be a solid piece of wood may consist in the interior of nothing but a series of galleries lined with white-ant mortar. These insects easily make their way into wooden boxes, and quickly destroy the books, papers, clothing, or whatever else they may contain. The rapidity with which they work is remarkable, and in a single night they have been known to burrow up through the leg of a table, then across the table, stopping on the way to devour the articles lying on it, and down through another leg into the floor again. Forest trees, also, are often ruined by the action of termites, which, in order to get at the dead branches will sometimes bore their way up through the trunk, and thus bring about its premature decay.

Book-Lice. The book-lice and the other insects classed with them in the family *Psocidæ* form another small group of Pseudoneuroptera. They are mostly very small insects, with a proportionately big head, swollen in front, and carrying prominent eyes, three ocelli, and bristle-like antennæ. Their mandibles are horny at the tip, but the other parts of the mouth are usually soft and membranous: the maxillæ being bilobed, with four-jointed palpi, and the palps of the bifid labium rudimentary. The middle segment of the thorax is the largest, and the prothorax is usually very short and narrow. The wings, which are wanting in some species, are slanting in repose, like the sides of a roof, and cover over the abdomen; they are of an almost glassy transparency, and have, as a rule, an open system of neuration. The tarsi are composed of two or three joints. Most species of *Psocidæ* live in the open air, and feed on fungi, lichens,

and the fragments of other plants; the largest European species (*Psocus lineatus*) being scarcely more than a quarter of an inch long.

Bird-Lice.

The Mallophaga, commonly known as bird-lice, are small wingless insects, resembling ordinary lice to some extent, but differing from them in many characters, and especially in the structure of the mouth, which is fitted for taking food by biting instead of sucking. They form a distinct group, now generally placed in the Pseudoneuroptera, though some entomologists assign it a position near the Pediculina or true lice. The bird-lice are flat-bodied insects, with a broad head, varying a good deal in form, and a thorax which usually appears to consist of only two segments. Their antennæ are short and composed of three, four, or five joints; and their eyes, when present, are simple. The mandibles appear as short hooks, sometimes toothed on the inner side; the maxillæ are short and said to be always palpless; while the lower lip is distinct and often bears palpi. The legs are short and stout, and have two-jointed tarsi, each of which carries at the end either one or two claws. As bird-lice are found on mammals as well as on birds, their name is to some extent misleading.



Psocus lineatus (enlarged three times).

TRUE ORTHOPTERA (*Orthoptera Genuina*).

The insects of this suborder differ chiefly from those of the last group in the characters of their wings, in which the two pairs are not formed alike. The fore-wings, which are usually stiff and tough, and in some cases horny, serve as wing-covers, and are generally spoken of as elytra; whereas the hind-pair are membranous, and capable of being folded longitudinally, or both longitudinally and transversely. The division of the ligula, or terminal piece of the lower lip into two or four lobes, is usually more complete than in the Pseudoneuroptera. It is usual to divide the true Orthoptera into two series or tribes—the Saltatoria, with strongly-developed hind-legs, adapted for leaping, and the Cursoria, in which the hind-legs are not thus developed, but are better fitted for use in running and walking. The saltatoria, or jumpers, are sometimes spoken of as the Musical Orthoptera, since nearly all these insects, such as crickets, grasshoppers and locusts, are noted for the loud chirping sounds which the males produce. The females are supposed to be attracted by the chirping of the males; they seldom emit any sound themselves, and when they do it is generally of a very feeble character. It is probable that most insects can hear, but by what means they do so is, in the majority of cases, to a great extent a matter of conjecture. The Saltatorial Orthoptera are, however, remarkable in possessing very definite organs of hearing, which, though occupying a different position, are functionally comparable to the ears of higher animals.

Crickets.

The crickets (*Gryllidæ*) which form the first family of the sub-order, have a somewhat rounded head, supporting long whip-like antennæ. Their mandibles are strong and toothed; the inner lobe of the maxillæ

being devoid of teeth, and the outer one long and slender. The fore-wings, or elytra, do not differ from one another in structure, and, when at rest, are closely applied to the somewhat thick and massive hind-body. The hind-wings are folded many times, and may generally be seen projecting beyond the tips of the elytra. The hind-legs are generally used in jumping, while the other two pairs are better adapted for walking, although in the mole-crickets the fore-legs are thickened and otherwise modified for use in burrowing. The tarsi of all the legs are composed of either two or three joints. The abdomen bears near the tip two flexible, velvety appendages, which are sometimes very long; and in the females it usually carries also a long exserted ovipositor. The chirping of crickets is produced by rubbing the base of one elytron over the other; in which respect these insects differ from most grasshoppers and locusts, and resemble only those grasshoppers with long antennæ, which belong to the family *Locustidæ.* They resemble the latter also in having their organs of hearing placed on the fore-legs. These organs are lodged in the upper part of the tibiæ, a little below their articulation with the



1-4, FIELD-CRICKET (*Gryllus campestris*)—(1) male, (2) female, (3 and 4) young and old larvæ; 5, MALE OF THE HOUSE-CRICKET (*Gryllus domesticus*).

femora, and consist externally of two small depressions or pits on opposite sides of each tibia, with a thin membrane stretched across the bottom of each depression. Inside the leg a tracheal vessel widens out between the two tympanic membranes, to form a vesicular expansion, on which are distributed the end cells and rods of a nerve which comes from the first thoracic ganglion. Crickets are found all over the world, but only four species are British. Of these one (*Nemobius sylvestris*) may be recognised by its small size, being little more than a third of an inch long. It is usually found among the dead leaves in woods, and appears to be restricted in its range to the southern counties. The field-cricket (*Gryllus campestris*), which sometimes measures an inch in length, is generally of a black colour, and lives in dry fields, where it is often heard though seldom seen on account of its retiring habits. The house-cricket (*G. domesticus*) has a reddish brown colour, and is somewhat smaller than the field-cricket. It has well-developed wings, and the female has a long ovipositor. The mole-crickets, of which there is one British species (*Gryllotalpa vulgaris*), have such a peculiar structure that they are easily distinguished from all other insects. They have a long, smooth, shiny prothorax; rather short, close-fitting elytra; and under-wings which, when

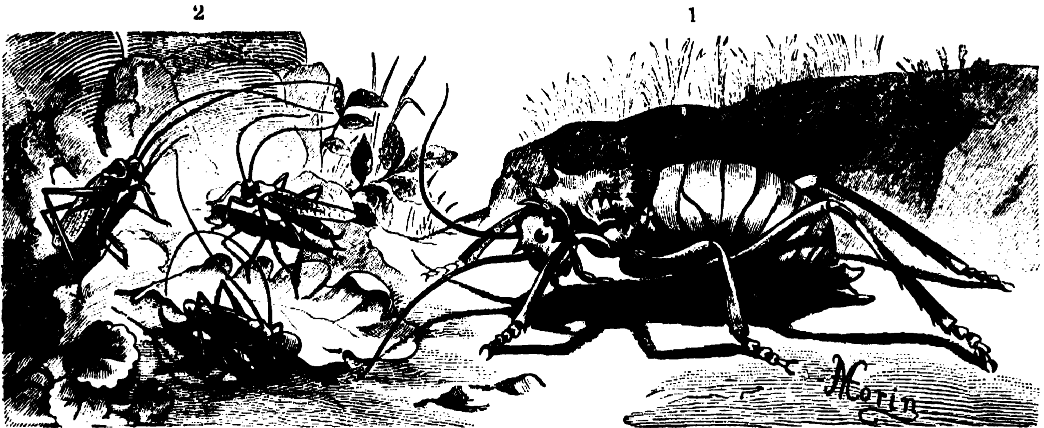
rolled up, look like a tail curving down over the tip of the abdomen. The abdomen itself carries two long flexible tails, which are said to be used like antennæ, when the insect runs backwards. It is, however, by the extraordinary shape of the fore-legs that these insects may be most easily recognised. These limbs are thicker, but shorter than the hind-legs; they have very short tibiæ, each ending below in four strong claws spread out like the fingers of a hand.



MOLE-CRICKET, WITH EGGS AND LARVÆ (slightly enlarged).

Long-Horned Grasshoppers. Although named *Locustidæ*, this family does not comprise the locusts, but includes only those grasshoppers in which the antennæ are long and tapering, and the tarsi are four-jointed; while the female is provided with a long ovipositor. Besides these characters, there are some others which help to distinguish the *Locustidæ* from the members of the next family. In the present group the organs of hearing are placed, as in the crickets, in the tibiæ of the fore-legs; and the chirping of the male is produced by the friction of the wing-covers over one another. The wing-covers, instead of being both alike, as in crickets, exhibit a certain amount of difference in the arrangement of the veins and structure of the membrane in their basal part. Taking the male of the large British green grasshopper as an example, it will be seen that on the portion of the right elytron which folds horizontally over the trunk, there is near the base a somewhat irregularly circular area, which has a glistening appearance, like a piece of talc. This area is bordered by a strong prominent vein. In a corresponding position on the left elytron, which, when closed, overlaps the right, there are also some thick transverse veins, but the cells enclosed by these veins have a similar texture to the rest of the membrane. When the insect rubs its left elytron rapidly over the right the veins projecting on the under side scrape on the margin of the mirror, and set the latter in vibration, thus giving rise to the well-known sound. The chirping of the *Locustidæ* is generally louder and more prolonged than in the other grasshoppers. In certain North American species known as katy-dids, the song seems to consist of these words repeated again and again, with a slight variation. The life-history of the *Locustidæ*, so far as it is known, does not differ in any essential respect from that of the *Acridiidæ*. It is probable that in most cases the

female uses her long ovipositor to lay her eggs at some depth in the ground, though in some species the female is known to deposit her eggs on plants. These grasshoppers are less herbivorous in their habits than those belonging to the next family; many of them are, in fact, believed to be more carnivorous than herbivorous in their tastes. The *Locustidæ* are most numerous in species in America and Asia; there being not many more than two hundred species in Europe, of which about ten are British. In the large green grasshopper (*Locusta viridissima*), which is nearly an inch and a half long, and is easily distinguished by its size from all the other British species, the male makes a harsh and strident noise, by which attention is attracted, when otherwise, owing to its green colour, it might altogether escape notice. Green is the prevailing tint in very many species of this family. In some species the elytra have the most exquisite resemblance in colour and venation to green leaves; while in others they look more like withered leaves. Nowhere is this style of protective coloration better displayed than in the exotic genera *Cycloptera* and *Pterochroza*, one of the species of which is figured in the



1, FEMALE OF *Hetrodes spinulosus*; 2, MALE AND FEMALE OF *Meconema varium*. (All nat. size.)

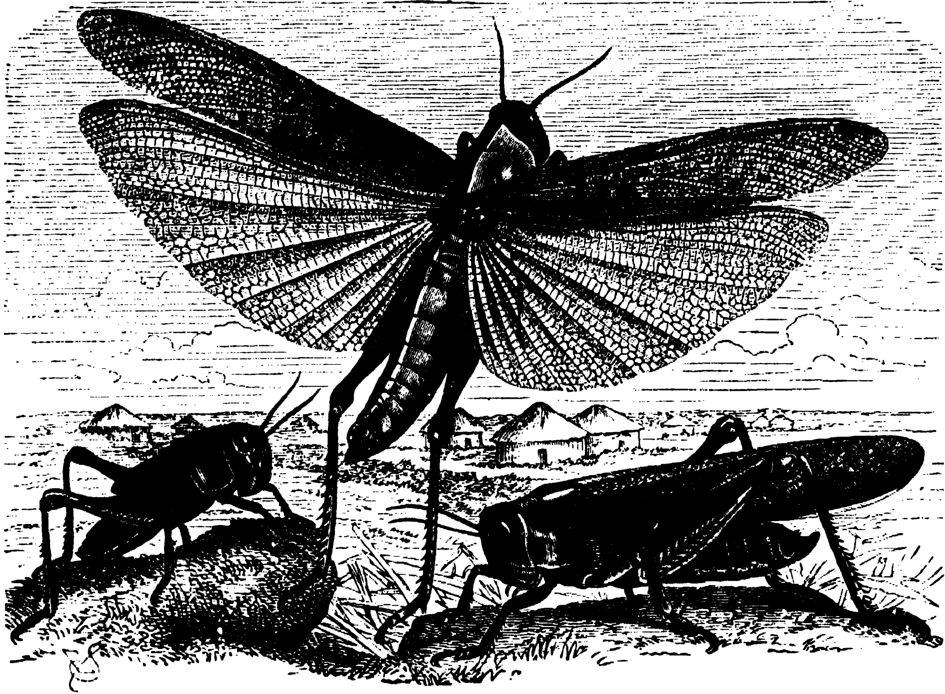
coloured Plate. The shape, colour, and venation of the wings are not only exactly like those of leaves, but there may be seen, here and there, little glistening, transparent patches of cuticle, which reveal, as it were, the work of an insect grub. In others, fungi seem to grow on the leaves, and leave their mark in the discoloured patches which may be seen scattered about. Amongst the species of the family remarkable in other respects we have space to mention only a few. In the genus *Hetrodes* the adult insects of both sexes are without wings; the prothorax is very large, and is armed above with a number of spines. An idea of the general appearance of the adult insect may be gathered from the figure of *Hetrodes spinulosus*. This species is found in Arabia and Syria. For the sake of contrast the male and female of a small British grasshopper (*Meconema varium*) are figured beside it. The latter is winged in both sexes; it is found in oak trees, and belongs to a subfamily which is peculiar from the fact that the elytra of the male have no stridulating organs.

Locust Tribe.

The locusts and short-horned grasshoppers (*Acridiidæ*) are distinguished by easily recognised characters from the other two families of the suborder. The antennæ are short, seldom attaining more than half the

length of the body, the tarsi are three-jointed, and the female always has a very short ovipositor. They differ also in the position of the auditory organs, and in the mode by which the males produce the chirping. In these insects the organs of hearing appear externally as two pits, somewhat crescentic or semilunar in shape, placed one on each side of the first abdominal segment, immediately behind the thorax. At the bottom of each pit there is a tense membrane, which on its inner side is brought into relation with the terminal rods and fibres of a nerve which arises from the last thoracic ganglion. It was thought that these pits were in some way concerned in the production of sound, but it is evident from their structure that this is not the case, while they really seem capable of serving no other function than that of ears. Moreover, it is now known that the chirping of these insects is produced by rubbing the hind-legs up and down against some of the projecting nervures in the sides of the closed elytra. When the insect is stridulating it keeps the tibia of the leg folded up against the femur. In some species the sound is heard at both the upward and downward stroke of the legs, in others at the downward stroke only. The sound varies in intensity in different species, and for this reason some of the commoner species may be recognised even before they are seen. In most of these insects the front of the head is vertical, or slightly inclined backwards, but in some (*Tryxalinæ*) it is much inclined backwards, and the whole head seems prolonged in a way that makes it look like a cone or wedge, with the antennæ and eyes near the apex, and the mouth placed below under its base. The *Acridiidæ* are usually provided with three ocelli in addition to the compound eyes, the ocelli being as a rule more distinct than in the *Locustidæ*. The mouth-organs are well developed, consisting of a large upper lip; strong, toothed masticatory jaws; five-jointed maxillary palpi; and a lower lip, divided at the end into two or four lobes, and bearing three-jointed palpi. The prothorax is generally large, much longer above than below, and often carrying a prominent crest along the middle. Wings are usually present, but the hind-pair are wanting in the females, or even in both sexes, of some species. In their general life-history the *Acridiidæ* are probably much alike. The female lays her eggs at a short depth below the surface of the ground, or attaches them to the stalks of grasses, and usually surrounds them, in mass, with some sort of protective covering. Later on in the same year, or in the spring of the year following, the larvæ are excluded. They soon become active, and—except that they are without wings, have shorter antennæ, and are of smaller size and no definite colour—do not differ much in appearance from the perfect insects. After undergoing, as a rule, about six moults, the larvæ which are hatched in the spring become adult late in the summer. It is generally in the days immediately following their entry into the perfect state that the male insects are loudest and most persistent in their song. Few of the British *Acridiidæ*, of which there are about a dozen, are remarkable for the brightness of their colours; nor do any cause trouble by a great excess of numbers. But amongst the exotic species there are many exhibiting vivid tints of colour; and some which are capable of multiplying to such an extent as to become a serious source of mischief in the places where they abound. It is to the species accustomed to assemble together, and migrate from place to place, in vast swarms, that the name of locusts is more especially applied; this habit really constituting almost the only difference

between the locusts and many of the other grasshoppers of this family. Grasshoppers feed chiefly on the grasses of different kinds, including most of the cultivated grains; but locusts leave scarcely anything in the nature of vegetation untouched, when, as often happens, they invade a district where the ordinary herbs and grasses are insufficient to support their vast numbers. Trees and shrubs are then stripped bare of their leaves, and the bark and wood even are not spared. Pressed by hunger, locusts do not refrain from attacking plants which at ordinary times they seem to avoid. They frequently devour their own dead, and even carry their cannibalism so far as to kill and eat the newly-moulted and soft-skinned larvæ. Different species of these destructive insects are found in all the great regions of the world; though North Africa is, perhaps, the one which



MIGRATORY LOCUST OF SOUTH-EAST EUROPE (*Pachytylus migratorius*) AND ITS LARVÆ (nat. size).

suffers most from their ravages. The locusts referred to in Scripture belonged in all probability for the most part to the species known as *Schistocerca peregrina*, which has its chief home in the Sahara and surrounding districts.

Several other species are found in North Africa, and in South Africa *Pachytylus migratorioides* is one of the most widely distributed. Great swarms of locusts of this species have been seen at different times in recent years; one which passed over Pretoria in 1891 was estimated to be twenty-five miles long, one and a half broad, and half a mile in depth. It was probably to this species also those locusts belonged, of which Barrow, giving an account of their ravages in the year 1797, states that the whole surface of the ground over an area of about two thousand square miles was literally covered with them; and that when driven into the sea by a north-west wind, they formed a bank on the shore three or four feet high and fifty miles long. Amongst European locusts, the best known is *P. migratorius*,

which occurs chiefly in the south-east, and is found also in Egypt and in West and Central Asia.

Passing from the locusts, we may briefly notice a few of the other insects of the family. The *Tryxalinæ* are remarkable on account of the peculiar shape of their head, to which we have already alluded. No species of this subfamily is found in Britain. In the allied *Tettiginæ* the pronotum is produced behind into a long process, which in some of the species reaches beyond the tip of the abdomen. Two of the smallest species of grasshoppers found in Great Britain belong to the genus *Tettix*—the typical genus of this subfamily. The genus *Pneumora*, which is represented only in South Africa, is characterised by the bladder-like dilatation of the abdomen in one of the sexes. The hind-legs in this genus are rather short, and are scarcely adapted for leaping.



Tettix subulata (nat. size).

Stick- and Leaf-Insects. The stick- and leaf-insects (*Phasmatidæ*) are chiefly interesting on account of their resemblance to the objects after which they are named. They form one of the families of Cursorial Orthoptera, and, in addition to the easily recognised shape of their bodies, are distinguished by the following characters. The head is distinctly visible from above, and is set somewhat obliquely, with the mouth placed well forwards on the under side. The short prothorax is much shorter, as a rule, than the next segment, or mesothorax. The legs which, in shape, usually harmonise with the shape of the body, are inserted somewhat close to the sides of the thorax, those of each pair being separated from one another by a rather broad sternal plate; the tarsi are five-jointed, and exhibit a pad-like lobe between the claws of the terminal joint. In the stick-insects the trunk is long, narrow, and cylindrical; the legs are generally long, and, when stretched out unsymmetrically from the body, as they habitually are in the resting insect, look like smaller branches coming off from a thicker, jointed stem. Many stick-insects have no wings at any stage of their life, and it is difficult, in such cases, to distinguish the adult insects from some of the older larvæ. In the winged species the fore-wings are usually very short, and often cover only a small part of the hind-pair; the latter exhibit a division into two distinct areas—one more membranous and transparent, and often brightly coloured; the other, which is narrower, and placed next the anterior border, being coloured like the elytra. When the wings are at rest, the brightly-coloured portion is folded beneath the other part, which alone is then exposed to view, so that there is nothing to detract from the general stick-like appearance of the body. These insects are usually found amongst underwood, or on shrubs and the stems of long grasses. They are mostly inactive during the day, and are not easily seen owing to the way in which their form and colours harmonise with their surroundings. They roam about at night,

and feed upon leaves. Most inhabit tropical and subtropical countries, and amongst them are some of the largest insects known, more than one measuring over 13 inches in length. Two species are found in South Europe, belonging to the genus *Bacillus*, and are both wingless forms of rather small size. One of these is figured in the illustration; and, as examples of some of the more finely-coloured tropical forms, two species from the island of Borneo are represented on the coloured Plate of Orthoptera.

The leaf-insects, though belonging to the same family, exhibit a marked contrast to stick-insects in the shape of the body, which, instead of being narrow and cylindrical, is broad and flat. The male is narrower than the female, and distinguished also by having moderately long antennæ, well-developed hind-wings, and short fore-wings. In the female the antennæ are very short, the hind-wings



ONE OF THE STICK-INSECTS OF SOUTH EUROPE (*Bacillus rossi*) AND ITS LARVA (nat. size).

are rudimentary; and the elytra are fairly large, leaf-like structures, which, in some species, almost entirely cover the broad, flattened abdomen. The legs have broad, leaf-like expansions on both the femora and tibiæ, contributing to the general leaf-like appearance. It is remarkable that the colour of these insects, which is either the green of a living leaf, or some shade of yellow or brown, like that of a withered leaf, is due to a substance similar in its nature to chlorophyll, or the green colouring matter of plants; and it is stated that the internal structure of the elytra bears a striking resemblance to that of a plant. All these curious insects belong to the single genus *Phyllium*, and are found in the Oriental countries, and in some islands of the Indian Ocean.

Praying Insects. The praying insects, or *Mantidæ*, constituting the next family of the suborder, have the head turned down, with the face inclined backwards, so that the vertex projects in front, while the mouth lies close to the lower edge of the prothorax. They have many-jointed, bristle-like, or comb-like antennæ. The prothorax is generally much longer than the other two segments of the thorax taken together; whereas the two hinder pairs of legs are long, and resemble one another. The fore-legs—which are inserted close to the front and wider end of the prothorax—exhibit a peculiar form and structure, their coxæ being long and three-cornered, and often spined on the angles, and the femora broad, flattened, and grooved below to receive the tibiæ, which can be folded back upon

them like the blade of a knife. The tarsi of all the legs are five-jointed. These insects usually have two pairs of wings, of which the fore-wings, or elytra, are ordinarily of the length of the abdomen. The characteristic posture which these insects assume when resting on a tree or shrub with their prothorax raised, and the fore-legs doubled up in front of them, accounts for their common names of soothsayers and praying insects. They are amongst the most predaceous and bloodthirsty of creatures, living on flies and other insects, which they seize with their raptorial fore-legs, in the manner shown in the illustration. *Mantidæ* are chiefly found in the warmer parts of the world, but a few species occur in South Europe. The best known of these is the figured *Mantis religiosa*. Some species, such as the African *Harpax ocellata*, shown on the coloured



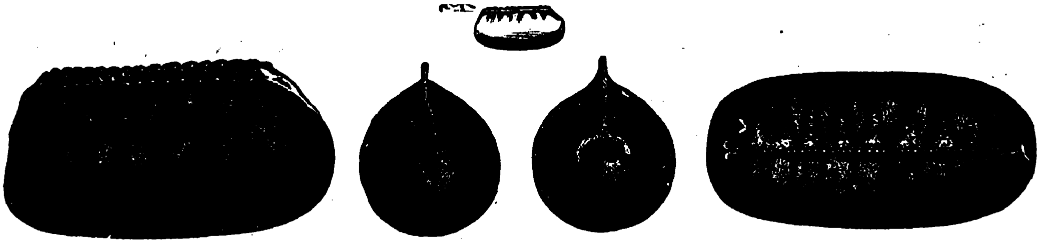
PRAYING INSECT SEIZING A FLY.
The egg-case and some of the escaping larvæ are shown at the left-hand side of the figure.

Plate, are curiously marked, while others are prettily coloured. The colours are sometimes so disposed that the insect in its resting attitude resembles a flower, and thus draws towards it other insects, which, when they have approached near enough, are suddenly caught, as if in a trap, by the arms of the deceiver.

Cockroaches.

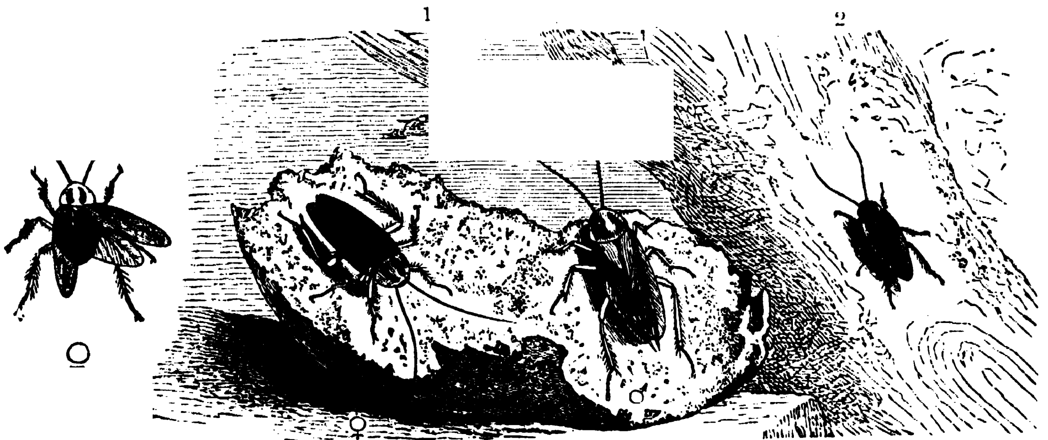
The cockroaches (*Blattidæ*) constitute one of those families in which the legs are more specially fitted for running. They have a rather short head, with a large, flat face, looking slightly downwards, and the mouth brought close to the prosternum. The eyes are large and compound, and in the place usually occupied by the lateral ocelli there are often to be seen two pale soft spots in the integument. The long and tapering antennæ are inserted close to the eyes, and composed of a stouter basal joint, followed by a number of short joints. The strong and horny jaws are toothed or spined on the inner side, and thus well adapted to biting; and the head is scarcely visible from above, being overlapped by the large, shield-like plate of the prothorax. The legs are long, with spiny tibiæ, and end in five-jointed tarsi. The pulvillus, which projects between the tarsal claws of these and many other insects, constitutes a sixth joint, although not usually reckoned as such. Cockroaches are generally provided with two pairs of wings, the front pair being stiff and horny, while the hind pair

are of a more membranous texture, and, in a state of rest, are folded longitudinally and almost entirely covered by the elytra. The abdomen is broad and flat, and carries two jointed appendages—the cerci—near its extremity. About six species are found in Britain, of which three only are really indigenous, the others having been imported. The common cockroach (*Periplaneta orientalis*) is believed to have belonged originally to the East, though now found in almost



EGG-CASE OF THE COMMON KITCHEN COCKROACH (the top figure nat. size, the others much enlarged).

all parts of the world. These insects are commonly spoken of as "black-beetles," though not beetles, and not black, but having a reddish brown colour. The male is easily recognised by the wings, of which there are two pairs, scarcely reaching beyond the middle of the abdomen. The female is broader in the body, and has very short rudimentary fore-wings and no hind-wings. Her eggs are arranged in a horny case, opening at the top, and shaped like a purse, which she carries about with her for some time, protruding from the end of her abdomen. She finally deposits the egg-capsule in a crevice in the walls or below the floor, and after some interval the young larvæ are excluded. During growth they shed their skin several times. The new skin is at first soft and of a pale or nearly white colour, but

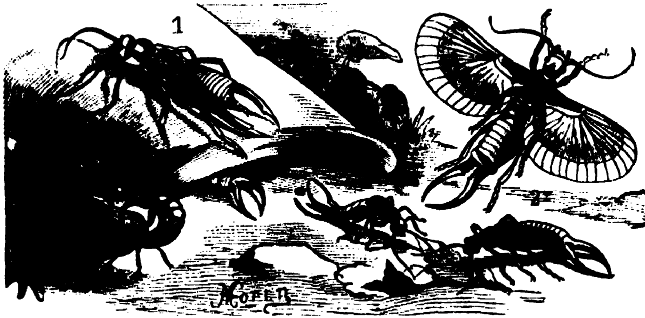


COCKROACHES.
1, *Phyllodromia germanica*, male and female; 2, *Ectobia lapponica*. (Nat. size.)

gradually hardens and gets darker. The American cockroach (*P. americana*) which is such a pest on many ships, and is found about the docks and warehouses of seaport towns, is larger than the common species. Although it somewhat resembles the latter in general colour, it has two pale bands on the prothorax, and is winged in both sexes. The German cockroach (*Phyllodromia*

germanica) is another imported species, said to have first arrived with the soldiers returning from the Crimean War, but now plentiful in some houses, especially in bakeries and restaurants. It may be distinguished by its smaller size, and pale yellow-brown colour, with two dark brown bands along the pronotum. Both sexes have wings. In some parts of Central Europe they live in woods, resembling in this respect many other species, including three, belonging to the genus *Ectobia*, found in woods in England. One of the latter (*E. lapponica*) enters houses in some parts of Europe.

Earwigs. The earwigs (*Forficulidæ*), which form the last family of Cursorial Orthoptera, possess distinct characters, and are sometimes treated as a separate order, under the name of Dermaptera. Easily recognised by the narrow body, short, squarely cut horny elytra, and the pincer-like appendages of their abdomen, these insects are further distinguished by the intricate folding of the hind-wings. The elytra, or fore-wings, do not overlap one another as in most Orthoptera, but, like those of beetles, simply meet by their edges along the middle line. The hind-wings, which are thin and membranous throughout most of their extent, are folded, partly like a fan, by means of folds radiating from near the middle of the anterior margin, and also transversely. In this way they occupy a small space, and are almost completely covered by the elytra, a tiny piece only being left projecting behind. When fully expanded, each wing is somewhat elliptic in outline, with a straighter anterior and more rounded posterior margin. To these characters it is only necessary to add that the tarsi are three-jointed, and the ligula of the lower lip is deeply divided, to form two long lobes. This family is represented in almost all parts of the world, but not more than two or three species are commonly met with in Britain. The species are distinguished chiefly by the size and shape of their forceps, the length and number of joints of the antennæ, the state of development of the wings (which in some species are altogether wanting), the length and shape of the tarsal joints, and other characters. The common earwig (*Forficula auricularia*), found all over Europe, is the best known species. The female is usually smaller than the male, and her forceps are shorter, and without teeth at the base. Her eggs are laid under stones, moss, or in other such places; and she watches over them with care. It was long ago observed that the female earwig sits over her eggs, like a hen in a nest, and if they happen to get scattered, gathers them all together again. The young larvæ when hatched keep close to her, clustering under her body, and sometimes climbing on to her back. They are not very unlike their mother in appearance, but are without wings, and of much smaller size. The large earwig



1, MALE OF THE LARGE EARWIG; 2, THE COMMON EARWIG, WITH AN ENLARGED FIGURE OF THE FLYING INSECT.

(*Labidura riparia*), found somewhat rarely in England along the south coast, is nearly twice the size of the common species, and its forceps has a large tooth beyond the middle of its length.

Order Rhynchota.

The numerous insects included in this order exhibit great differences in their external form, and while some, such as the *Flatinæ*, rival the butterflies and moths in the beauty and delicacy of their colours, others are amongst the most loathsome of creatures. But whatever be their form or colour, all agree in two essential characters, the first consisting in the fact that their development takes place without a complete metamorphosis; and the second that all have the mouth taking the form of a beak, or rostrum, adapted for piercing and sucking. The beak consists chiefly of the lower lip (labium), which is long and narrow, composed of three or four joints, and grooved along the whole length of its upper or anterior surface. This groove forms a sort of sheath, in which are lodged four long slender blades, corresponding to the mandibles and maxillæ of other insects, but here transformed into piercing organs. All these parts are covered at the base in front by the narrow and slightly elongated upper lip (labrum). From the structure of their mouth, which is fitted only for the reception of liquid nutriment, it is easy to infer that these insects live by piercing tissues of plants and animals, and extracting the juices. The larvæ differ little from the adults except in size, the absence of wings, and their usually shorter and more slender antennæ. In many, however, the females are without wings at all stages; and in some cases both sexes are thus unprovided. When wings are present, they may be all of similar texture, or the front-pair may be somewhat stiffer and less membranous than the hinder. Wings of both these kinds are found in the section Homoptera. In other cases, while the hind-wings are entirely membranous, the front-pair are stiff and horny for some distance from their base, and thin and membranous towards their extremities. Such wings, which characterise the section Heteroptera, are known as hemi-elytra. Over eighteen thousand species are already known. Fossil remains of the order are found in strata of the Jurassic epoch, and are tolerably abundant in amber and other beds of Tertiary age.

All the Heteroptera, no matter how different they may be in external form or mode of life, are termed bugs, although this name was originally applied only to the bed-bug and a few closely-allied species. Most are winged insects, in which the fore-wings known as hemi-elytra, or simply as elytra, always have the form described above. Their antennæ are either short and inconspicuous, as in the water-bugs, or distinctly visible as in the land-bugs, and are generally composed of a small number of joints. As a rule they have two compound eyes, and often two or three ocelli. The first segment of the thorax is usually large, with the head sunk deeply into it. The abdomen generally has an oval flattened form, and the legs are mostly slender. With few exceptions bugs are characterised by a peculiar and somewhat unpleasant odour, which arises from a liquid secreted by special glands placed in the front part of the abdomen, and opening to the exterior by means of two small ostioles on the ventral surface of the metathorax.

Land-Bugs. Bugs are divided into two tribes, based upon their mode of existence, and the fact that in one tribe—the land-bugs, or Geocorisa—the antennæ project, and are distinctly visible, while in the other—the water-bugs, or Hydrocorisa—they are very short, and hidden below the eyes. The shield-bugs (Pentatomatidæ), which constitute one of the largest families of the Geocorisa, are so called on account of their large scutellum, which reaches at least to the middle of the abdomen, and sometimes quite to its extremity, covering it over completely. The fore-wings are sometimes chitinised only near the basal margin, especially in those species with a very large scutellum. The body has in general an elliptical outline, or is shaped like a scutcheon, owing to the projecting lateral angles of the somewhat hexagonal pronotum. These bugs are mostly found on low plants, some in concealment, many showing themselves openly, and often attracting observation by their striking colours. The adults pass the winter sheltered under bark or dried leaves. In early spring the females lay their eggs on the foliage of low plants, shrubs, and pine trees. The oval or spherical eggs are provided with an operculum, or lid, and disposed in patches resembling honeycomb. The larvæ moult several times in the course of their growth, and thus gradually effect a change in their form and coloration. They feed on the juices of plants, or, in some cases, of animals, and attain their full size towards the end of summer. The European species are rather limited in number; but many forms are found in other parts of the world. The Hottentot bug (*Eurygaster maurus*) is the name given to a species with a very large scutellum, found throughout nearly all Europe. It is of a yellow, dark brown, or black colour, with two clear spots on each side of the base of the scutellum. Some rather pretty bugs of the genus *Scutellera*, belonging to the same subfamily, and characterised by a similar large scutellum, are found in Australia and the Eastern Archipelago. They are of a short, broad, and convex form, and have a very fine metallic-blue coloration, often spotted with bright yellow. The forest-bugs (*Pentatoma*) have strongly projecting angles to the prothorax, and have a long triangular scutellum. The species figured (*P. rufipes*) is common throughout Europe, on birch and other trees, and renders service by destroying certain caterpillars. We figure on the opposite page three other species of this family—*Acanthosoma dentatum*, which is common on willows; *Eurydema oleraceum*, a bluish green or metallic green species, with red or white markings, which in some places is injurious to plants of the cabbage tribe, but also lives on other plants, and has often been seen to prey upon insects; and another common species met with near the outskirts of woods and in fields and meadows.


HOTTENTOT BUG (nat. size).

The family *Coreidæ* includes a number of land-bugs, which vary a good deal in form, but which possess in common the following characters,—antennæ four-jointed, set rather high up on the head; two ocelli generally present; scutellum short and triangular; elytral membrane strongly and thickly veined. These bugs

mostly inhabit the warmer parts of the world, not more than about sixty species being found in Europe. Their habits are not very well known. Some of the European species live during the winter under leaves, and when disturbed in their retreat make by their movements a peculiar rustling sound. In summer they are to be found among herbs and shrubs seeking their food, or they may sometimes be seen flying actively in the sunshine. Our figures—one representing a stout, strongly-built insect (*Syromastes marginatus*), the other a species (*Neides tipularius*) with a body as slender almost as that of a daddy long-legs—illustrate what considerable differences of form are met with in this family, even among the common European species. The *Lygæidæ*, the next family of land-bugs, may be characterised as follows,—antennæ four-jointed, arising from below an imaginary line drawn from the middle of the eye to the base of the rostrum; two ocelli usually present, and placed close to the compound eyes; sheath of rostrum composed of four nearly equal joints; scutellum short and triangular; membrane of elytra traversed by four or five longitudinal veins. They live, for the most part, under stones, dead leaves, or moss at the foot of trees, where they are often found together in large numbers; and it is from their love of such obscure places that the name *Lygæus* has been given to the typical genus. They feed on the juices of plants or the dead bodies of other insects. A few species only show themselves in broad daylight. The species of the genus *Pyrrhocoris*, and others associated in the same subfamily, are distinguished by the fact that they have no ocelli. *P. apterus* is a common and widely-spread European species, occasionally



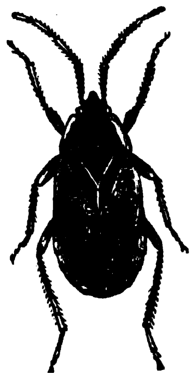
SHIELD BUGS.

1, *Pentatoma rufipes*; 2, *Acanthosoma dentatum*; 3, *Eurydema oleraceum*; 4, *Aelia acuminata* (nat. size).

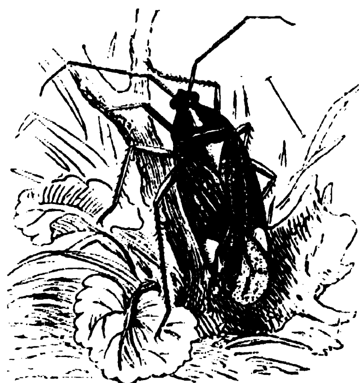


1, *Syromastes marginatus*; 2, Larva of the same; 3, *Neides tipularius* (nat size).

met with in Britain, which may be known by its red and black colours, and the want of hind-wings, as well as of a membranous part to its elytra. The plant-bugs (*Phytocoridæ*) have the following characters. Head triangular in shape, tricarinate above, and without ocelli; antennæ long, four-jointed, with the second joint longest, and the last two very slender; rostrum four-jointed, resting against the under side of the thorax, and almost reaching to the end of it; tarsi three-jointed; elytra with an *appendix*, or small angular piece, divided off by a transverse suture from the rest of the coriaceous part of the elytra, and coming between it and the membrane. This family is well represented in temperate regions, and about three hundred European species are known. They are mostly soft-bodied, fragile bugs, presenting a considerable variety of colour, of which green is in many cases the predominant tint. They live principally on honey, and are to be found on flowers and in meadows. *Phytocoris tripustulatus*, a species with black elytra, marked with three orange spots on the outer margin, is common on nettles. We give an enlarged figure of another species (*Calocoris striatellus*), widely distributed throughout Europe, and met with chiefly on umbelliferous plants. The *Acanthiidæ* form a family of mostly very small bugs, which are usually without ocelli, and have a three-jointed beak—lodged in a groove along the under side of the head—and two-jointed tarsi. These bugs frequently have a somewhat peculiar appearance, owing to the membranous or vesicular lobes with which the thorax, abdomen, and elytra are often furnished. For this reason they are sometimes known as membranaceous bugs. The species of the genus *Tingis* are seldom more than one-sixth of an inch long, and distinguished by the knob-like ends to their antennæ, as well as by the foliaceous expansion of their thorax, and the extension of the latter behind to cover the scutellum. The common *T. affinis* may be recognised by the brown colour of its body, its transparent borders, with transverse brown nervures, and the ×-shaped spot on the middle of each elytron. This species may be found on sandy soil among the roots of grasses, or under plants, such as wormwood, belonging to the genus *Artemisia*. Another species (*T. pyri*) is noted for the injury it does to pear trees, by pricking holes in hundreds on the under side of the leaves and extracting the sap. It is of a brown colour, with pale yellow or white elytra, marked with a brown spot at the base and another at the extremity. *Aradus corticalis* is a common species, found under bark, which we figure to give an idea of the flattened form and membranous appearance of the bugs of the sub-family *Aradinæ*. These bugs have a longer rostrum and more cylindrical antennæ than those of the *Tingitinæ*. The bed-bug (*Cimex lectularius*), which also belongs to this family, is a wingless species, with four-jointed antennæ, and a beak composed

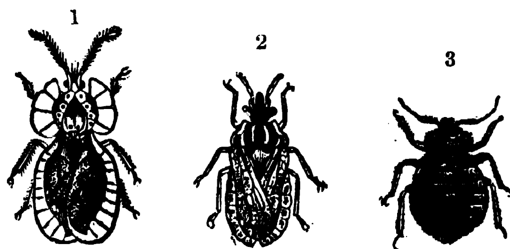


Pyrrhocoris apterus (three times the nat. size).

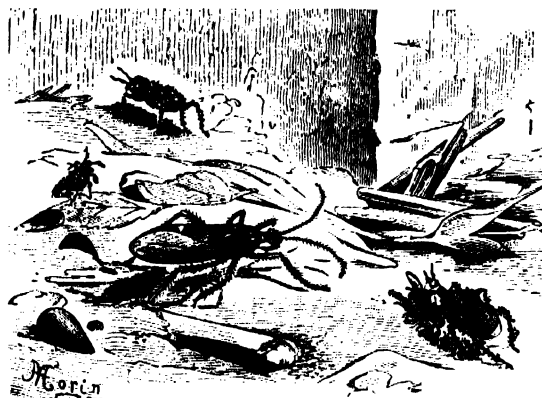


Calocoris striatellus (much enlarged).

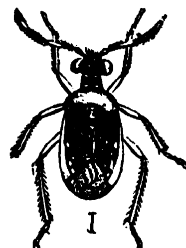
also of four joints, which can be turned back to lie in a groove under the throat. The shape of the insect may be seen from the figure, as well as the two lobes lying at the sides of the scutellum, which are all it has in the way of elytra. Closely-allied species are found in dovecots, and in the nests of martins and bats. The *Reduviidæ* are predaceous bugs, in which the head, narrowed behind in the form of a neck, carries two ocelli in addition to the compound eyes. Their antennæ are composed of four joints, though these are often subdivided in such a way that the number may appear much greater. The rostrum is short and strong, and three-jointed; their legs are long, and have three-jointed tarsi; and the fore-legs often serve as prehensile organs, their tarsi being specially adapted for that purpose. *Reduvius personatus*, the largest British species, is three-quarters of an inch long, of a black-brown colour, with red legs, which, as well as the prothorax and antennæ, are somewhat hairy.



Tingis affinis (×8); 2, *Aradus corticalis* (×6); 3, *Cimex lectularius* (much enlarged).


Reduvius personatus and its larva (nat size).

The *Saldidæ*, which, on account of their large projecting eyes, are sometimes known as Oculati, form with the next family a sort of transitional group between the land-bugs and water-bugs. They live in the neighbourhood of water, either by the seashore or along the sandy banks of inland waters; and not only run with great rapidity, but often advance with leaps and bounds, their long spiny hind-legs being well fitted for this mode of locomotion. One of the species of the typical genus *Salda* is represented in the illustration. The pond-skaters (*Hydrometridæ*) have moderately long conspicuous antennæ, and present other points of structure showing that they are nearly related to the true land-bugs. In some species wings, and in others, elytra also, may be wanting. These insects may be seen walking or gliding about on the sunny surface of stagnant or slow-flowing waters; and those of one genus (*Halobates*) are found on the surface of the sea, sometimes right out in mid-ocean. The true pond-skaters (*Gerris*) move about very quickly on the surface of the water, and use their fore-legs in seizing their prey. *Limnobates stagnorum* is a more sluggish insect, walking slowly on the surface of the water, or on the grassy banks; and is remarkable for its elongated slender body, whence its name of needle-bug or water-gnat. This species is figured on p. 192, together with *Gerris paludum* and the larva of *Velia currens*.



Salda elegantula (greatly enlarged).

Water-Bugs.

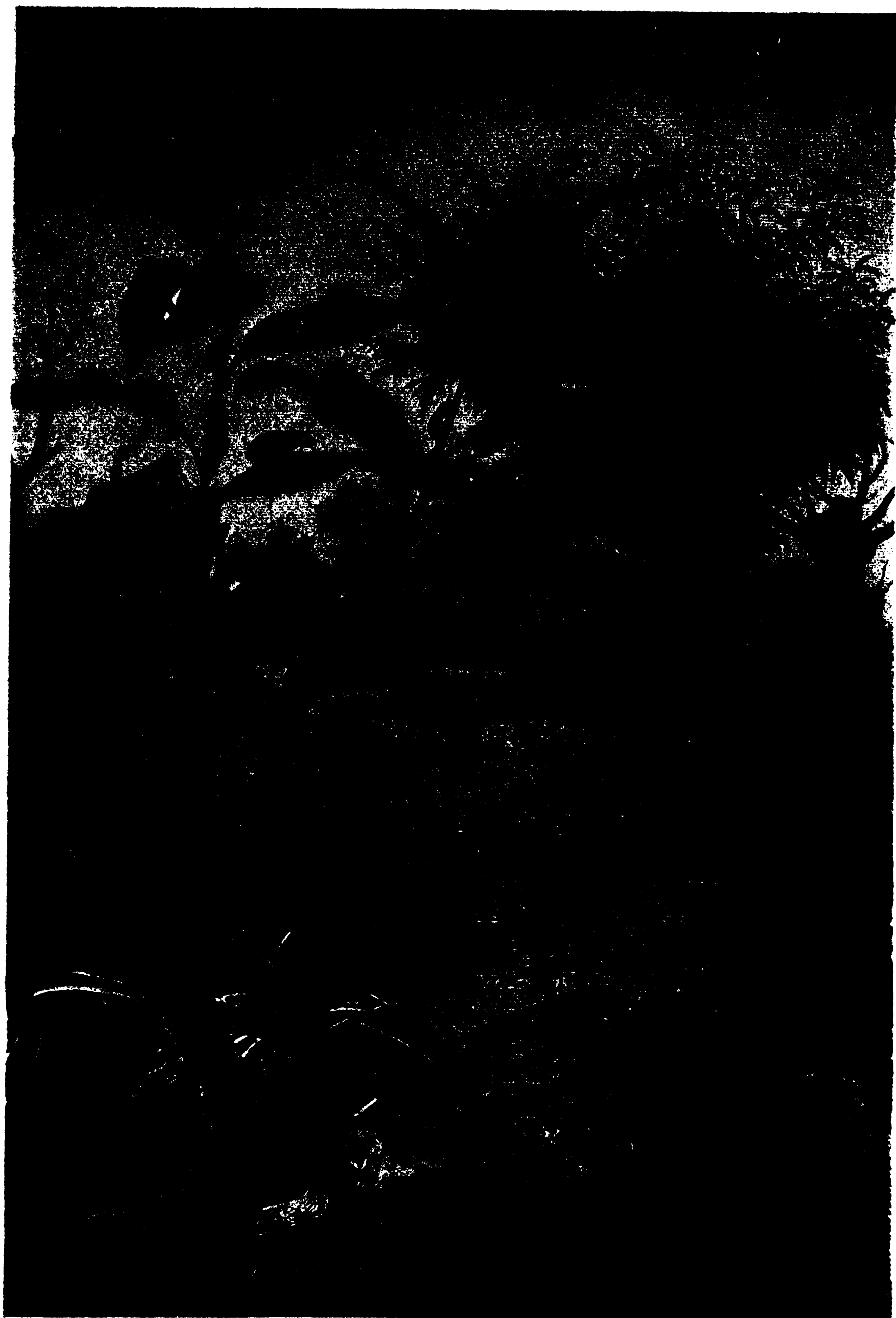
The water-bugs, Hydrocorisa, are distinguished from the land-bugs, not only by their mode of life, but also by their short inconspicuous antennæ, and are mostly dull and uniformly coloured insects, frequenting stagnant waters, where they swim some on their back, others with the back uppermost. They are all comprised in two families. Of these, the water-scorpions (*Nepidæ*) have a small narrow head, and their fore-legs are specially modified to serve as prehensile organs. Whereas some swim actively, others drag themselves slowly along the



COMMON BRITISH WATER-BUGS.

1, The water boatman (*Notonecta glauca*); 2, The water-scorpion (*Nepa cinerea*), with (3) its larva and (4) its eggs; 5, *Naucoris cimicoides*; 6, *Corixa geoffroyi*; 7, *Ranatra linearis*; 8, *Limnobates stagnorum*; 9, Pond-skater (*Gerris paludum*), with (10) its eggs and larvæ; 11, Larva of *Velia currens* (nat. size).

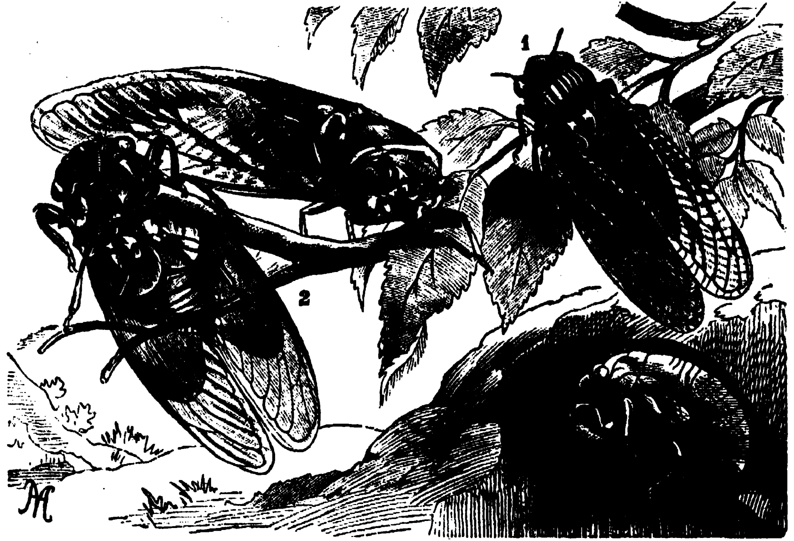
bottom of the ponds in which they live. They are furnished with an appendage looking like a long tail, but consisting of two separate pieces, grooved on their inner surface, and capable of being locked closely together to form a tube, which leads to the two spiracles placed at the hind-end of the body. When the insects come up to breathe, the tip of this breathing-tube may be seen emerging just at the surface of the water. The form of the body is in some (*Nepa*) broad and flat; in others (*Ranatra*) elongated. The female of *Nepa* lays her eggs in chains on aquatic plants, and each egg has seven short processes radiating from one end. The eggs of the *Ranatra* are laid one by one in notches, which the female makes in the stems of the plant.



BEETLES IN A FLOOD.

...ic species of this family are remarkable for their great size, attaining in the genus *Belostoma* a length of over 4 inches. The water-boatmen (*Notonectidæ*) may be recognised by the large broad head without ocelli, and the short thick rostrum. They have long hind-legs fringed with hairs on one side, which they use like oars in swimming. When the insect comes to the surface to breathe, it rests with these long legs, stretched out like a boatman leaning on his sculls. Though the name *Notonectidæ* has reference to their mode of swimming on the back, this habit is not characteristic of all the species. All are predaceous bugs, like all the rest of the same tribe, and are found abundantly in stagnant waters. Two of the common species, *Notonecta glauca* and *Corixa geoffroyi* are figured on p. 192.

The Homoptera present much greater variety in external form than the insects of the preceding group, from which they differ in the following characters. The beak arises from the lower and hinder part of the head, and is, therefore, almost completely hidden from view. The fore-wings are, when present, of the same texture throughout the whole of their extent, and, in many cases, placed slanting, like the sides of a roof, when at rest. All the members of the section live by sucking the juices of plants; the females being often provided with a horny ovipositor—generally composed of three toothed plates, sheathed by two valves—for the purpose of making incisions in plants where the eggs are deposited. Unlike most bugs, they are not odoriferous insects, although many have special glands for the secretion of a kind of white waxy substance, often seen covering part of their body. The cicadas (*Cicadidæ*) are stout-bodied insects, with a short broad head, bearing prominent lateral eyes, and three distinct ocelli, which are often brightly coloured and resemble tiny jewels set near the middle of the forehead. The short antennæ are like small bristles inserted on the sides of the head just below the front margin of the eyes. The prothorax is short and broad, and the mesothorax also broad, on the upper side stretching back some distance behind to form a kind of shield. The fore-wings are longer than the hind-pair, both being often glossy and transparent, but sometimes finely coloured and more or less opaque. Cicadas remain for a long period in the larval state, in many cases for several

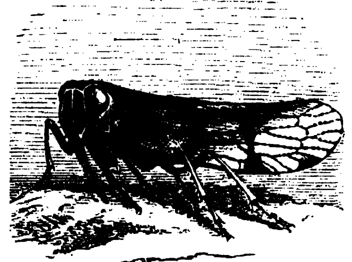


EUROPEAN CICADAS.
1, *Cicada orni*; 2, *C. plebja* and larva.

years; a North American species, *Cicada septemdecim*, being known as the seventeen-year locust, since that period is the interval between one generation of winged insects and the next. They inhabit chiefly the warmer regions of the earth, of the four or five hundred species known, not more than eighteen being found in Europe, and these mainly in its southern parts. The song of the cicadas, which has been celebrated from very early times, is only produced by the male insects. "Happy" writes a Greek poet, "are the cicadas' lives, for they all have voiceless wives." The females are necessarily silent, since they are without the special apparatus for producing sound distinctive of the males. The two scaly plates which in the latter cover the under side of the base of the abdomen, are not, as sometimes supposed, the sound-producing organs. But if one of them be stripped off, there will be disclosed a cavity, divided by an oblique horny ridge into two portions, the inner one somewhat irregular in shape, and exhibiting tense glistening membranes in its walls, while the outer portion is narrow, and opens by a narrow mouth towards the side. Hidden in the wall of the latter chamber lies the membrane which is the chief organ concerned in the production of sound. These membranes are set in vibration by the contraction and relaxation of a pair of strong muscles attached to their inner faces and lying inside the body. The other membranes in their neighbourhood seem to serve the purpose only of modulating the sound. The cicadas figured are two of the commoner species from South Europe. Both live on ash trees, although *Cicada orni* selects by preference the manna ash. The specimen with its under side exposed may be easily recognised as a male, on account of the two plates, or opercula, covering the cavities in which the sound-apparatus is lodged.

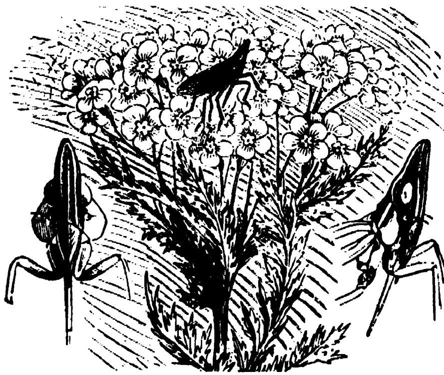
The lantern-flies and other insects included in the family *Fulgoridæ* are characterised by never having more than two ocelli, these being placed, one on each side, near the inner margin of the compound eyes. The latter are not large, and below them are inserted the short and inconspicuous antennæ. The front, vertex, and sides of the head are usually separated from one another by sharp crests, and the head itself is in some cases greatly prolonged in front. The fore-wings are either similar in texture to the hind-pair, or else somewhat harder and more leathery. The Chinese lantern-fly (*Hotinus candelarius*), so widely distributed in Asia, is one of the best known; the common names said to be given to it in China being very suggestive of its luminosity, although so far there is no trustworthy evidence to show that it possesses any such property. Lantern-flies are nearly all prettily coloured; and of the other insects belonging to the same family there are some, like those of the genus *Flata*, rivalling in the delicacy of their colours the most beautiful butterflies or flowers; while others, as in the genus *Flatoides*, exhibit that curious mixture of grey and black, which, in combination with the flattened form of their bodies, gives them the most astonishing resemblance to lichen-covered bark. The species of *Flata* and other genera are remarkable also for their white tufted tails of wax, which are found more especially in the larvæ, but are often present also in the winged insects. These insects do not stir far from their food-plant, on which they may be seen both in the larval and adult state, clustered together in large numbers, somewhat after the manner of plant-lice.

The European species of *Fulgoridæ* are not remarkable for their size or the brilliancy of their colours. *Issus coleoptratus* is perhaps the largest British species, and we figure *Cixius nervosus*, another widely distributed British and European species, together with *Pseudophana europæa*, the sole representative in Europe of its genus, and sometimes spoken of as the European lantern-fly.



Cixius nervosus (enlarged).

The frog-hoppers (*Cercopidæ*) are mostly small insects with a short broad head and stiff opaque elytra. They usually have two ocelli placed on the vertex of the head between the compound eyes; and their antennæ are inserted, not below the eyes as in the *Fulgoridæ*, but between and a little way in front of them. These insects can give most vigorous leaps, and their hind-legs are generally thickened or otherwise adapted for that purpose. They feed on various plants, and in the summer the frothy masses in which their larvæ lie concealed may be seen in numbers. It is from this habit the larvæ have of surrounding themselves in a mass of froth, known as cuckoo-spit, that the name *Aphrophora* (froth-bearing) has been given to one of the principal genera. A species of that genus is shown in the illustration on p. 196, where another form (*Ledra aurita*) — remarkable for an ear-like lobe on each side of the prothorax — is also figured. The family *Membracidæ* includes mostly exotic insects, which have in many cases an extraordinary appearance, owing to the shape of the prothorax, or the curious way in which it is armed with spines or knobs, or with both combined. In these insects the head is somewhat vertical, and usually placed rather low down; it carries very short antennæ inserted near the front margin; and there are two ocelli between the compound eyes. The family is best represented in Tropical America, very few species being found in Europe, and two only in Britain. *Centrotus cornutus*, one of the two latter, may be recognised by the form of its prothorax, which carries on each side a horny spine, and is prolonged behind in another horny process, reaching almost to the end of the body.



Pseudophana europæa.

The leaf-fleas (*Psyllidæ*)—included with the next two families in that section of the order to which the name Phytophthires has been given—are little jumping insects, winged in both sexes, and using their wings not so much for the purpose of flying as to assist in their leaps. They have moderately long antennæ, consisting of eight or ten joints, and are thus easily distinguished from the *Cercopidæ*. The head is provided with three ocelli, in addition to the compound eyes; and the tarsi are two-jointed. Owing to their method of locomotion, these insects are not liable to be mistaken for plant-lice, although, like these insects, they infest the leaves and buds of plants. They prick the leaves to

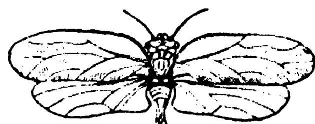
feed on the sap, their puncture being often followed by the formation of gall-like swellings. The figured *Psylla genistæ* feeds on the broom, but other species are found on apple and pear trees. The plant-lice (*Aphidæ*) are small insects, which make up in numbers what they lack in size, and, owing to the injury they inflict on plants, must be ranked amongst the greatest pests with which the gardener and horticulturist have to contend. They are those soft, pulpy little creatures, with rather long antennæ and conspicuous round eyes, so commonly seen crowded together on the under side of leaves, in buds and flowers, in clefts in the bark of trees, and sometimes even on the roots. The antennæ are composed of from three to seven joints, on some of which are a number of curious rounded pits, probably of a sensory nature. The eyes are placed on the sides of the head, and each has often a sort of supplementary eye attached to its hind border; while in the winged aphides there are three ocelli on the crown of the head. The beak is composed of three joints; and the tarsi are two-jointed and terminate in two claws. Wings, as a rule, are found only in the adult males and in some of those generations of asexual individuals to be mentioned presently. The fore-wings are longer than the hind-pair, and placed in repose like a roof over the hind part of the body. Both pairs have a scanty venation, consisting in each wing of a single longitudinal vein, and of some simple or forked branches given off obliquely from it. The number of species is considerable, and there is scarcely a single kind of plant that does not suffer as the special host of some one or more. Many are green, whence the name of green-fly by which they are commonly known; others are black, red, or some other colour. They are usually named after the plants on which they more particularly live, though each species is not necessarily confined to one kind of plant. Thus we have the plant-louse of the rose (*Aphis rosæ*); the green aphis of the apple (*A.*



1, *Ledra aurita*; 2, The same seen from the side (both enlarged); 3, *Aphrophora spumaria*; 4, Larva of the same.

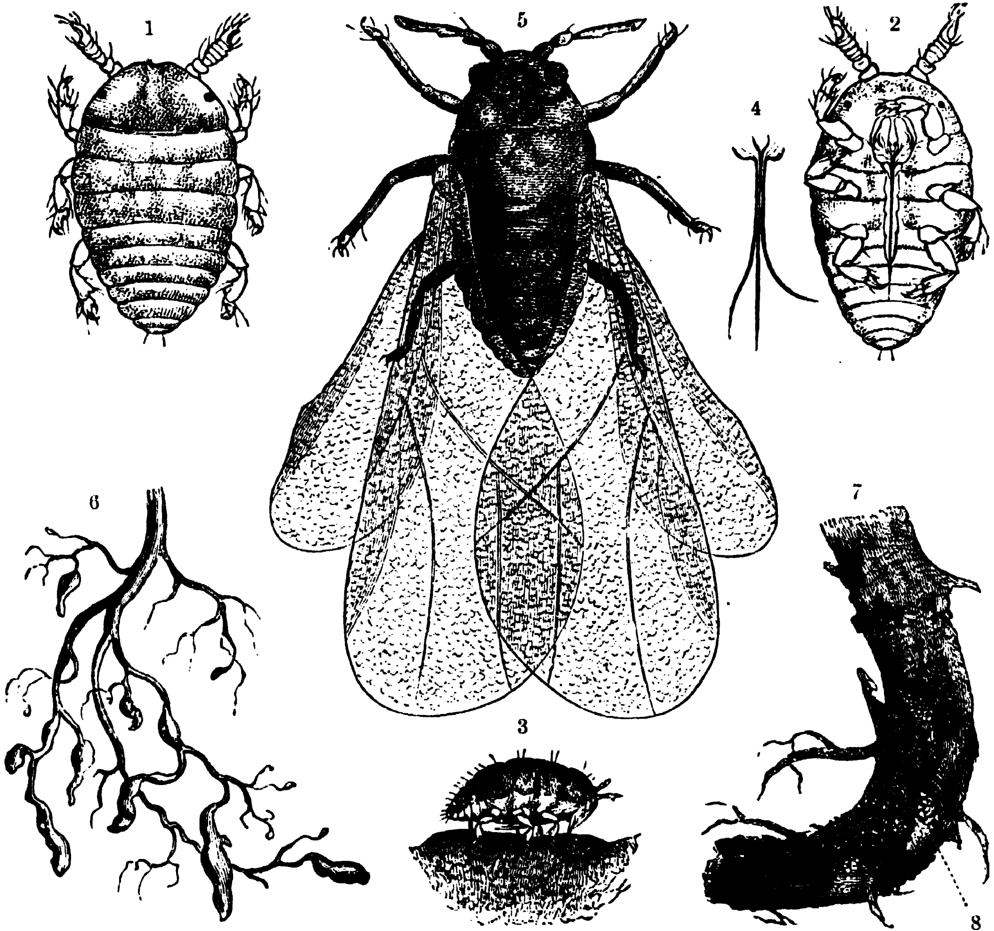


Centrotus cornutus (slightly enlarged).



Psylla genistæ (six times nat. size)

mali), which is found also on the pear and sloe tree; the cherry aphis (*A. cerasi*), and a host of others named in the same manner. The life-history of plant-lice is very complicated; and although differing somewhat in different species is always characterised by what is known as an alternation of generations. There are several broods or generations of these insects in the course of a year, but it is only in the last autumn brood that true sexual individuals are found. The males are generally provided with wings, but the females are larger

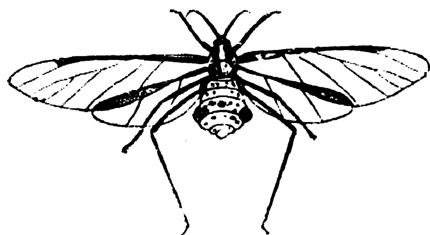


VINE-PHYLLOXERA (much enlarged).

1 and 2, The wingless form found on the root, seen from above and below; 3, The same from the side; 4, Its piercing organs; 5, Winged individual; 6, Rootlets of the vine, with swellings caused by the Phylloxera; 7, An old root stock, with (8) hibernating individuals.

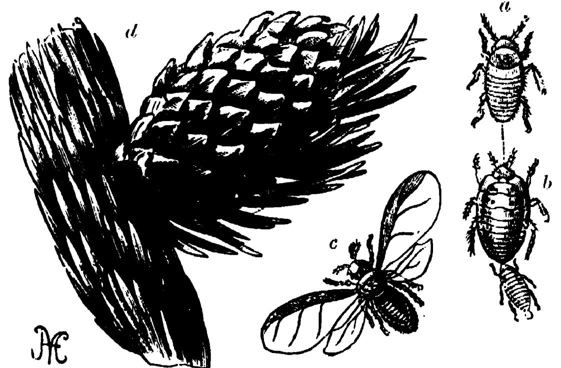
and wingless; they lay fertilised eggs, from which, in the following spring, the first brood of the year is produced. The insects of this brood are usually wingless, and give birth to living young, or, as in the genus *Phylloxera*, lay eggs from which the young subsequently develop. The new brood, thus produced parthenogenetically, resembles the one from which it has sprung, and gives rise to a fresh brood in a similar manner. As many as nine or ten generations may succeed one another in this way during the course of the season, before the appearance in the autumn of the last or sexual generation. The brood preceding and

giving rise to the latter often consists of winged individuals, which leave the plant on which they were born and fly to some other. In the genus *Phylloxera*, the males are wingless and each of the sexual females lays but a single egg, known as the winter egg; but in other forms the number is often much greater. Each of the parthenogenetic females of *Phylloxera* may in the course of its life lay as many as two hundred eggs, and each of the viviparous females of other species may give birth before they die to forty or fifty young. When we consider that there are several generations every year, it can be easily understood how it is that these insects spread with such rapidity; and a sum in geometrical progression would show that the individuals which might arise in the course of a year from a single winter egg of *Phylloxera*, are not to be counted by hundreds or thousands, but by millions. Other species are capable of multiplying as rapidly. Fortunately, plant-lice have many enemies, such as the larvæ of lady-bird beetles, of lace-wing flies, and of the flies of the family *Syrphidæ*. These larvæ devour great numbers, and ichneumon-flies also help to keep them in check. Plant-lice are divided into a number of subfamilies, of which the first is represented by the genus *Aphis*. In this genus the antennæ are seven-jointed and about as long as the body; the two horny tubes called *cornicles*, which project from the back of the abdomen, are also characteristic. Through these tubes the lice secrete a sweet kind of liquid much sought after by ants, who, in an affectionate way, come and caress the aphides in order to obtain it. The sticky substance known as honey-dew, which is often spread in a shiny layer over the upper surface of leaves, is, in most cases, nothing but the liquid dropped by the crowds of plant-lice living above on the under side of other leaves. The members of the allied subfamily *Lachninæ* have six-jointed antennæ, and instead of cornicles possess prominent grandular structures placed on the back of the abdomen. The figured *Lachnus punctatus* is found on the willow. The apple-blight insect (*Schizoneura lanigera*), which may be recognised by the white fluff covering in the wingless individuals the back of the abdomen, belongs to another subfamily. The winged individuals of this species are black, whereas those devoid of wings are of a yellowish or reddish brown colour, and live in the crevices of bark. The species is supposed to have been introduced from America, and was consequently at first known as American blight. In the genus *Phylloxera*—distinguished among other characters by the three-jointed antennæ—one species lives on the leaves of the oak-tree, while a second (*P. vastatrix*) is the dreaded insect so destructive to the leaves and roots of the vine. These, like many other species of the family, cause the formation of galls on the leaves and roots which they attack. The curious galls with the appearance of small fir cones, so often seen on young shoots of the spruce-fir, are caused by a species (*Chermes abietis*) remarkable for its complicated life-history.


Lachnus punctatus (six times nat. size).

The scale-insects (*Coccidæ*), which owe their name to the fact that the larvæ and females of many species look like oval or rounded scales attached to the bark and leaves of plants, are very dissimilar in the two sexes. The adult males are

provided with one pair of wings; the hind-wings being rudimentary or altogether absent; they have rather long antennæ, distinct eyes, and, in some cases, are furnished with two long bristle-like tails. These winged males are very rarely seen, which is accounted for by the fact that their mouth-parts are atrophied, so that they are incapable of taking nourishment, and live only a short time. The females are always wingless, and usually remain fixed to one spot, with their beak buried in the tissues of the plant, and their back often spread out in the form of a shield covering the head and body. The beak is generally three-jointed, the antennæ are short, and in the tarsi, which appear at first sight to consist of but one joint,



SPRUCE-GALL APHID (*Chermes abietis*).
Larva; *b*, An older larva with its moulded skin still attached to it; *c*, Winged insect; *d*, The gall. (All enlarged.)

two or three joints may on close examination be distinguished, the last ending, as a rule, in a single claw. In many species the female dies shortly after laying eggs beneath her when her body dries up and remains as a protective cover for them. When the larvæ are hatched they soon leave this shelter, and rove about the food plant in search of a suitable place in which to insert their beaks and begin the operation of pumping up the sap. They cast their skin several times in the course of their growth; and those which become adult females undergo no great change in appearance, beyond an increase in their size, a gradual lengthening of the antennæ, and a partial or almost complete obliteration of the segmentation of their bodies. With the male larvæ the case is different; these, unlike all others belonging to the order, undergoing a true metamorphosis before reaching the perfect state. Each prepares for itself a sort of cocoon, and it becomes transformed into a quiescent pupa, from which, after a certain lapse of time, the winged insect emerges. In *Orthezia* and other genera the female, instead of keeping to one spot on the food-plant, moves about and taps it at different points in order to extract the sap. When the eggs are laid, she envelops them in a kind of white cottony secretion and leaves them. Some species penetrate beneath the epidermis of their food-plant, and often cause the formation of galls, which, growing up around them, sometimes take the most extraordinary shapes. Scale-insects are probably more numerous within the tropics than in more temperate regions, although comparatively few of these tropical species have been described. These insects are found on the bark and leaves, and sometimes


FEMALE OF *Orthezia urticæ* (nat. size).

even on the roots of several different kinds of plants. They multiply rapidly, and often prove as injurious as the most noxious plant-lice. The orange, apricot, olive, peach, fig, and other fruit trees, as well as ornamental shrubs like the rose, have each their own species, from which they sometimes suffer severely. Some years ago the orange-plantations of California were threatened with ruin owing to the ravages of *Icerya purchasi*, which had been accidentally imported from Australia, and had spread with great rapidity. Experts were sent to Australia to try and discover the natural enemies of the insect in its native country; it was found that the scale-insect was there kept in check by dipterous and hymenopterous parasites, but chiefly by the larvæ of a lady-bird beetle. A number of these beetles and parasitic insects were brought to America, and set to prey upon the *Coccidæ*. When they had multiplied sufficiently, they were distributed amongst several orange-plantations, with the result that many were soon almost entirely cleared of the scaly-bug. Though many species

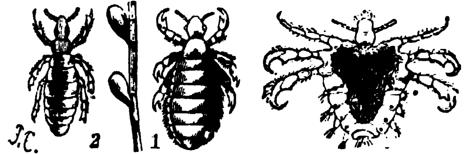


COCHINEAL INSECT (*Coccus cacti*), with enlarged figures to the left of (1) the male and (2) female.

of *Coccidæ* have to be combated because of their injuries, there are a few which are cultivated on account of the useful products they yield. Among these, the cochineal insect (*Coccus cacti*) is a native of Mexico and other parts of Central America, where it feeds on a species of cactus; but it has been introduced into Spain, Algeria, and a few other countries. The male is of a dark red colour, with pale wings; the female has a reddish brown colour, but her body, which shows a distinct segmentation until the time of laying, is covered with a white powder. About seventy thousand dried bodies of these insects, chiefly females, are said to be contained in a single pound of cochineal. Long before the introduction of cochineal into Europe, two native species of *Coccidæ* had been used for similar purposes. The dye with which the ancients produced their deep red or crimson colours was obtained from *Cermes vermilio*, known to the Greeks as kokkos and to the Arabians and Persians as kermes or alkermes. Another species (*Porphyrophora polonica*), formerly known as the scarlet grain of Poland, is found in many parts of Central Europe, and was at one time extensively collected for the sake of the red dye it afforded. The lac-insect (*Carteria lacca*) of the Oriental countries,

not only furnishes the colouring matter called lac-dye, but causes also an exudation of a resinous substance, gum-lac, from the bark of the trees on which it lives. Stick-lac is the name given to this substance in its native state while still adhering to the twigs of the tree; when separated, pounded and freed by washing from its colouring matter, it is known as seed-lac, which after further preparation becomes lump-lac or shellac.

The Pediculina, or true lice, as distinguished from the bird-lice of the order Orthoptera, are provided with piercing and suctorial mouth-parts, and live on the blood of animals, to which by this means they are enabled to gain access. Though they are without wings, and were at one time associated with other wingless insects in a separate order, lice are now generally regarded as degraded forms of Rhynchota, in which the wingless condition has been brought about as an adaptation to their parasitic life. In these insects the head is set horizontally, and carries short, cylindrical, and usually five-jointed antennæ; the eyes are small and simple; and the mouth consists externally of a soft, retractile beak, somewhat conical in shape, and furnished below with a row of hooks for attachment. Within the fleshy beak there are four grooved pieces, forming by their juxtaposition an inner membranous tube, which can be extended beyond its sheath, and acts both as a piercing organ and as a conduit for the passage of the blood which is sucked up by the insect. The thorax is small and not distinctly divided into segments, while the abdomen is relatively large, generally somewhat elliptical in outline, and exhibits seven or eight clearly marked segments. The tarsi are two-jointed, with the second joint in the form of a claw which can be turned back towards the first. Lice multiply rapidly, one generation succeeding another in a short space of time. Their pear-shaped eggs are generally found attached to the bases of the hairs; the young, which are hatched after about eight days, undergo no metamorphosis, and, in some cases, require only about eighteen days before becoming adult.



1, HEAD-LOUSE WITH ITS EGGS; 2, BODY-LOUSE; 3, CRAB-LOUSE. (All greatly enlarged.)

Order THYSANOPTERA.

The insects comprised in this order—some of them familiar enough to gardeners and others, by whom they are known as thrips—are all small. A few species only exceed four or five lines in length, while the great majority are less than a tenth of an inch long. They are distinguished from all other insects by certain peculiarities in the structure of their mouth and of their wings and tarsi. The mouth lies far back on the under side of the head; its mandibles are transformed into a pair of piercing setæ, while the upper lip, maxillæ and labium—the two latter, provided with short palpi—are united together to form a short suctorial tube. The wings are small and narrow, contain few nervures, and are thickly fringed all round with long hairs. Two pairs of such wings are generally present, but in some cases they may be rudimentary or altogether wanting. The tarsi, which consist of one, two, or three joints, are without claws at the end, but are

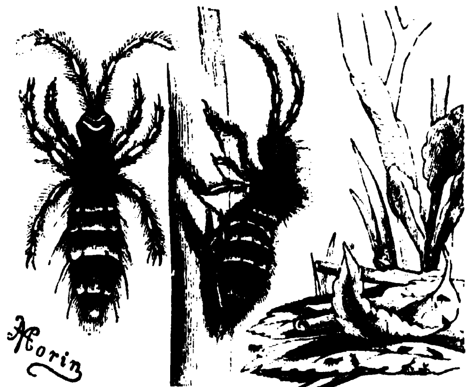
furnished instead with small vesicular lobes, by means of which they adhere to the surface on which they rest. To these characters of the order we may add that the body is narrow and cylindrical; the thorax is formed of three, and the abdomen of ten segments; there are only three or four pairs of spiracular openings —two on the abdomen, and one or two on the thorax; three ocelli are generally present on the head in addition to the fairly large faceted eyes; and the antennæ are composed of from seven to nine joints. The larvæ have a general resemblance to the adult insects, and in their last stage they remain inactive and take no nourishment. Less than a hundred species of Thysanoptera, belonging mostly to the European fauna, have been described. These little insects are frequently to be seen on flowers, and on other parts of plants. They feed upon the juices, and when present in large numbers are capable of doing an appreciable amount of injury. Some destroy the pollen grains, and so prevent the fertilisation of the flowers. The corn-thrips (*Thrips cerealium*) sucks the young grains on the ears of corn, and stops their further growth. *Heliothrips hæmorrhoidalis*, another species which we figure, is common in hothouses, where it may be found on the young buds of several different kinds of plants.


FEMALE CORN-THRIPS (much magnified).


Heliothrips hæmorrhoidalis (greatly enlarged).

Order THYSANURA.

The Thysanura are active little insects, which live generally in obscure places and are mostly of too small a size to attract much attention. They never exhibit any trace of wings, undergo no metamorphosis, and have a distinctly segmented body, which is usually covered with hairs or scales and furnished behind either with a forked tail, used as a springing apparatus, or with two or three long, jointed appendages, which sometimes serve a similar purpose. Characterised on the whole by a somewhat primitive type of structure, and, in general appearance resembling the larvæ rather than the adult forms of other insects, the Thysanura are in some cases distinguished by special features of great interest. The spring-tails (Collembola) are all furnished on the under side of the first abdominal segment with a curious tube or sucker, from the mouth of which a glandular process, secreting a viscid matter, can be protruded; they are remarkable also from the fact that in most of them no trace of a tracheal system has yet been discovered. In the Collembola the eyes, when present, are in the form of simple or grouped ocelli; the antennæ number not more than six joints, and the


Podura villosa (nat. size and greatly enlarged).

abdomen has at most but six segments and very often only three. The forked tail, which is attached to one of the hinder segments, is usually turned forwards and held in position under the body; when released, it springs back, striking the surface of support, and causes the insect to bound up into the air. These little insects are to be found commonly enough under flower-pots, leaves, and stones, or under the bark of trees and in other such situations. They may sometimes be seen collected together in great numbers, and spread over the surface of the ground like a layer of powder. Some species, such as *Podura aquatica*, may frequently be seen floating in patches on pools of water, and by striking their tails against the surface of the water, they can spring up into the air just as readily as others do from the ground. *Desoria glacialis* is an interesting species, found in Alpine regions, where it is often to be met with on the surface of the ice. The bristle-tails (Thysanura proper) form but a small number of genera, some of which are very remarkable in having a series of small rudimentary legs on each side of the abdomen in addition to the ordinary six legs borne by the thorax. In all the genera the antennæ are formed of a large number of joints; and the abdomen shows ten distinct segments, and, except in the genus *Japyx*, carries at the end two or three long jointed tails. *Japyx* has instead a pair of short pincers like an earwig. The little silver-fish (*Lepisma saccharina*) is one of the best known insects belonging to this suborder. Found very often in damp corners in houses, among old books or papers, it may be recognised by the silvery scales covering its body, and by its three bristle-like tails, of which the middle one is the longest. It feeds on the paste in the binding of books, and on sugary and starchy substances generally, though it is credited also with eating paper and linen. *Thermophila furnorum* is a species which lives in bakehouses, where, as its name implies, it is often found in the ovens.



Desoria glacialis (greatly enlarged).

Machilis is one of the genera in which the abdomen is provided with rudimentary legs in the form of small cylindrical appendages, each of which is accompanied by two small protrusible sac-like organs. An appendage similar to those on the abdomen is attached to each of the coxæ of the two hinder pairs of legs. The body, covered over with scales, is arched up in the middle, as in *Lepisma*, and carries three tails. The eyes are large and faceted; and the palpi are long, those of the maxillæ looking like a second pair of antennæ. Two species of this genus are found in Great Britain; one being common about rocks at the seaside, while the other is to be met with under stones in different parts of the country. *Campodea staphylinus*, the last insect we have to mention, is a pale, soft-bodied little creature, which is common almost everywhere under stones and in loose garden soil. It runs actively, and has two very long tails which it sticks up in the air or turns forward over its body. It has no eyes; the antennæ are shorter than the tails and of equal thickness throughout; and the abdomen has seven pairs of rudimentary appendages.

C. J. GAHAN.

CHAPTER VI.

JOINTED ANIMALS,—*continued.*

CENTIPEDES, MILLIPEDES, SCORPIONS, AND SPIDERS,—Classes **Chilopoda, Diplopoda, Arachnida, etc.**

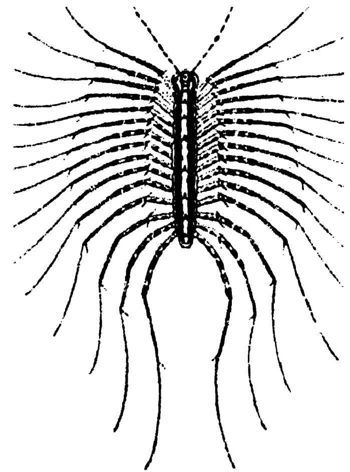
Characters of Centipedes. ACCORDING to modern views, centipedes are regarded as near allies of insects, the chief differences between the two groups being that whereas in the latter there are only three pairs of jaws attached to the lower surface of the head, in the former four pairs of appendages are modified to act as masticating organs. Moreover, the body of an insect is sharply divided into an anterior portion, or thorax, bearing three pairs of walking legs, and a posterior half, or abdomen, which in the adult at least is not provided with locomotor limbs, but the body of a centipede is composed of a large and varying number of segments, substantially alike in structure, and each bearing a single pair of legs. The number of segments varies from fifteen to considerably over one hundred, yet no matter how many pairs of legs there may be—whether it be fifteen or one hundred and twenty-one—their number is invariably odd.

The head bears a pair of elongate antennæ in front, and often eyes arranged in two clusters at the sides. On its lower surface may be seen the four pairs of jaws. The first pair, or mandibles, are two-jointed and have a biting edge; the second pair, or maxillæ, are soft, leaf-like, and united together in the middle line, each consisting of an outer jointed and an inner unjointed branch. The third pair, known as the first maxillipedes, are composed of four or five segments, and much resemble one of the walking limbs, being tipped with a claw. The fourth pair, or second maxillipedes, are large, powerful, and project forwards below the rest, so as more or less to conceal them from view. Their basal segments are usually fused to form a massive coxal plate, while the rest of the jaw consists of four segments, the terminal one being a long fang with a minute aperture at the tip, through which exudes poison secreted by a gland lodged inside the appendage. These two pairs of maxillipedes do not strictly belong to the head, since the dorsal elements of the segments that bear them are either distinct, or are united with the tergal plate of the following segment to constitute a massive basilar plate.

The rest of the body is composed of a varying number of segments, each consisting externally of a dorsal plate or tergum, and a ventral plate or sternum, connected laterally by a softer pleural membrane, to which the legs are articulated. These latter are usually short, composed of six or seven segments, and each is tipped with a single claw, and often furnished in addition with spines. The last pair are generally longer and stronger than the rest, and sometimes considerably modified

in structure. Breathing is effected by tracheal tubes, which open by means of stigmata, placed almost always upon the pleural membrane of the segments.

Centipedes are divided into two subclasses—Anartiostigma, or those with unpaired dorsal stigmata, and Artiostigma, or those with paired lateral stigmata. In the former group, which contains the single family *Scutigeridæ* and the genus *Scutigera*, the head is furnished with a pair of large, compound, faceted eyes, the widely separated antennæ are exceedingly long and thread-like; and the body, although composed of fifteen segments, has only eight dorsal plates, all of which except the last are furnished in the middle of the hinder border with a single large respiratory stigma. The first pair of maxillipedes consists of five segments, and the coxæ of the second pair, or poison-jaws, are not united; the legs are very long and their tarsi composed of a multitude of minute segments. The species of the genus *Scutigera* are distributed over all tropical and subtropical countries. Most are of small size, with the body only about an inch in length, but in India and China there are species (*S. longicornis* and *S. clunifera*) which may reach a length of several inches. The majority are vividly coloured with black and yellow stripes or spots, and all are remarkable for their extreme agility, and the readiness with which, when handled, they part with their legs. None are indigenous to Britain, but the common South European *S. coleoptrata* has been introduced into a paper-mill near Aberdeen, where, protected by the artificial heat, it has become established, and breeds. Unlike the rest of the centipedes, which habitually shun the light, the species of *Scutigera* may be seen in their native haunts darting about and catching insects regardless of the blazing sun. They are, however, by no means strictly diurnal, and the American *S. forceps* will come out in numbers at night to feed on flies.



BLACK-BANDED CENTIPEDE, *Scutigera*, (nat. size).

In the Artiostigma the stigmata are paired, and open upon the pleural membrane of all or some of the segments. There are the same number of tergal as of sternal plates; the eyes, when present, are not faceted, but consist of simple ocelli; the antennæ are stouter and not thread-like; the first maxillipedes consist of four segments, and the coxæ of the poison-jaws are united. The subclass contains the orders Lithobiomorpha, Scolopendromorpha, and Geophilomorpha. The first of these approaches the Anartiostigma in many characters, particularly in being furnished with fifteen pairs of legs, the coxæ of which are of large size; and in one of the genera (*Cermatobius*), which forms by itself the family *Cermatobiidæ*, the tarsi of the legs are many-jointed. There are either six or seven pairs of stigmata, situated upon the first, third, fifth, eighth, tenth, twelfth and fourteenth leg-bearing segments in *Henicops* and *Cermatobius*, while those on the first have disappeared in *Lithobius*. In the latter genus, which with *Henicops* makes up

the family *Lithobiidæ*, the eyes consist of a cluster of ocelli on each side of the head, while in the other two there is only one pair of ocelli. Except in *Cermatobius*, the coxæ of the last five pairs of limbs are furnished with organs known as the coxal pores, which are the apertures of special glands.

The members of this order are found in all temperate and tropical regions, living often in pairs under stones, logs of wood, etc. The species of *Lithobius* are particularly abundant, and reach their largest size in the temperate parts of the Northern Hemisphere. A few only have been recorded from India and Australia, but none occur in Africa south of the Sahara, nor, with the single exception of a possibly introduced species in South America. In the Southern Hemisphere the genus is largely replaced by *Henicops*, which is represented in Europe and North America by a single small species, but has many larger forms in South Africa, Australia, New Zealand, and Chili. The single species of *Cermatobius* occurs in Halmahira, one of the Moluccas. There are about half a dozen species of *Lithobius* in the British Islands, one of the commonest and largest being *L. forficatus*, represented in the figure. Almost equally common and equally large, although seldom found close to houses, is *L. variegatus*,—a brightly-coloured species with banded legs,—which is confined to the British and Channel Islands. The largest known species is the handsome *L. fasciatus*, measuring 2 inches in length, and occurring in many of the southern countries of Europe. In all cases the females—which may be recognised by the presence of a pair of dwarfed, claw-tipped appendages behind the last pair of legs—lay their sticky eggs one at a time, and roll them in the soil until they become coated with earth, and consequently protected from observation. The young, like those of *Scutigera*, are hatched from the egg with only seven pairs of legs, the remaining eight pairs being added during growth. The food of these centipedes consist of worms, insects, etc., which are killed by the poisonous bite of their destroyer.



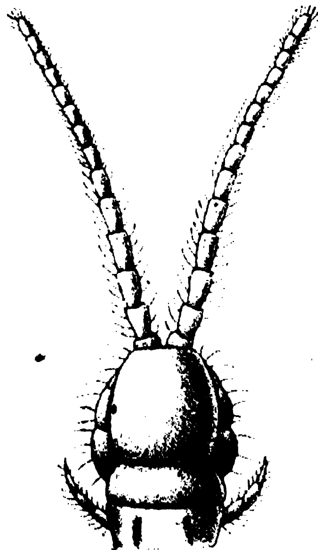
COMMON ENGLISH CENTIPEDE (nat. size).

The second order, or Scolopendromorpha, contains the giants of the group, some of the tropical species of *Scolopendra* reaching a length of almost 12 inches. The legs vary in number from twenty-one to twenty-three pairs, and there are either nineteen pairs of stigmata, as in the aberrant genus *Plutonium* from Italy, or more usually nine or ten pairs situated upon the third, fifth, eighth (sometimes also the seventh), tenth, and alternate segments of even number. The eyes are either absent or consist of four ocelli on each side of the head, and the segments of the antennæ vary in number from seventeen to twenty-nine. The members of this order are referable to four families, the *Scolopendridæ*, *Scolopocryptopidæ*, *Newportiidæ*, and *Cryptopidæ*. Both the *Scolopocryptopidæ* and *Newportiidæ* have twenty-three pairs of legs, but in the latter, which is confined to the South American region, the legs of the last pair are clawless and have their terminal segments many jointed and evidently functioning as antennæ, so that the

centipedes may be said to have a pair of feelers at each end of the body. The *Cryptopidæ* resemble the preceding in being blind, but have only twenty-one pairs of legs. They are all of small size, rarely exceeding an inch in length, and are spread all over the world, extending farther to the north than any other forms. One, namely, *Cryptops hortensis*, is by no means uncommon in England. The most important forms belong, however, to the *Scolopendridæ*, which in number of genera and species is far superior to the others. Like the *Cryptopidæ* they have twenty-one pairs of legs, but the tarsi of these appendages are bisegmented, and there are four eyes on each side of the head. From the shores of the Mediterranean in the west, and from China and Japan in the east, this family spreads southwards over the entire Eastern Hemisphere, while in America it ranges from the Southern United States to Chili and Argentina. The larger members of the group are a foot in length, and very venomous, although their bite is seldom fatal to man. The *Scolopendridæ* live under stones and logs, and in the tropics frequently take refuge in bedding, boots, or clothes. Their food consists principally of cockroaches, beetles, worms, etc.; but they do not seem to be particular as to diet, since some have been found devouring lizards of larger size than themselves, and one kept for more than a year in the London Zoological Gardens was fed upon mice. The female lays her eggs in clusters like berries on the ground in some damp obscure place, and coiling herself round them remains immovable until the young are hatched and have gained strength enough to scatter in search of prey. When kept without food in captivity the mother will feed upon her young. The growth of these centipedes, and probably of all members of the group, is accompanied by casting of the entire integument. The membrane at the back and sides of the head splits, the head-plate turns forwards, and through the aperture thus made the new centipede gradually struggles, leaving behind the old skin with its posterior segments retracted within those that lie in front like the pieces of a telescope. The genera of *Scolopendridæ* present a strong family likeness to each other; one of the most remarkable being the African *Alipes*, which has the last three segments of the last pair of legs flattened and leaf-like. The reason of this modification is unknown, but the creature is said to make a noise by knocking and rubbing its legs together.



CENTIPEDE (*Scolopendra morsitans*) DEVOURING A BEETLE LARVA (reduced).



UPPER SURFACE OF HEAD OF *Geophilus tenuitarsus* (much enlarged).

The order Geophilomorpha, represented by the family *Geophilidæ*, includes the long worm-like centipedes, with the segments varying in number from thirty-nine to over a hundred. There are no eyes, and the short thick antennæ are always composed of fourteen segments. Each segment of the body, with the exception of the first and last, bears a pair of stigmata and is double, an anterior portion being cut off by a distinct joint. The *Geophilidæ*, which are distributed all over the world, with the exception of the polar areas, are subterranean in their habits, burrowing after the manner of earth-worms, upon which they almost wholly subsist. Two exceptions, however, to this rule must be mentioned, namely, *Linotænia maritima* and *Schendyla submarina*, both of which have been obtained upon the shores of Western Europe, beneath stones at low-water mark. Although this is a strange habitat for animals, air-breathing species typically terrestrial can withstand immersion in sea-water for many hours, and in fresh water from one to two



GEOPHILUS GRAPPLING WITH EARTH-WORM (nat. size).

weeks. Many of the species emit a phosphorescent fluid from glands opening upon the sternal surface of the segments. In Europe the time for the appearance of the phenomenon is between the end of September and the beginning of November. Although its import is not understood, it appears to be connected in some manner with the mating of the sexes. A small reddish species (*Linotænia crassipes*) is the one most commonly found exhibiting this phosphorescence in England.

Remains of fossil centipedes referable to the existing groups occur in amber beds belonging to the middle portion of the Tertiary period; while more aberrant types have been discovered in the Palæozoic rocks of the United States.

To a certain extent, connecting the centipedes with the millipedes and insects, is the class Symphyla, containing the single genus *Scolopendrella*. This is represented by minute pale-coloured creatures, with long thread-like antennæ, fifteen or sixteen body-segments, and twelve pair of legs, each of which is armed with two claws. It further differs from the centipedes in having only two pairs of jaws, as in the millipedes. *Scolopendrella*, which includes two British species, also occurs in North America, India, and Sumatra.

THE MILLIPEDES,—Class **Diplopoda**.

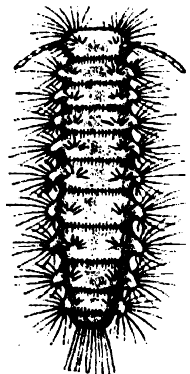
Although millipedes and centipedes were formerly united to form the class Myriopoda, it has been discovered that the characters in which they resemble each

other are comparatively trifling, and that the present group is much less closely related to the insects than are the centipedes. In addition to certain anatomical features, millipedes differ from centipedes in the following points. They have only two pairs of jaws, namely, the mandibles—which are usually three-jointed—and the maxillæ, which unite to form a large plate or gnathochilarium, acting as a lower lip. Besides these two pairs of appendages, the head is furnished usually with two clusters of eyes, and always with a pair of short antennæ, never composed of more than eight segments, and usually of seven. The body consists as in the centipedes of a varying, often large, number of segments, some of which are furnished with two pairs of legs, and thus represent two primitive segments fused together. These segments are usually cylindrical in section, and although each



A SUMATRAN MILLIPEDE, *Platyrrhachus mirandus* (nat. size).

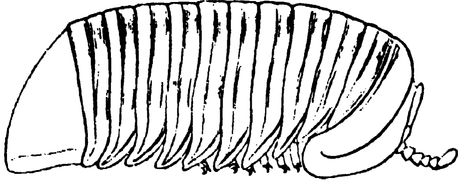
may consist of as many as five skeletal pieces, these are frequently fused together to form a single horny ring. The sternal surface, or the area between the bases of the legs, is generally reduced to a narrow strip, the legs being almost or quite in contact in the middle of the lower surface. The stigmata or breathing apertures are placed close to the base of the limbs on their outer side; and in addition to these apertures, there is often a pair of orifices in each segment (except the last and the first four) giving exit to an odorous fluid which serves as a protection to its possessors. The legs are short and generally composed of six segments, tipped with a single terminal claw. The last segment is devoid of appendages, and furnished with a pair of movable flaps or doors, closing over the hinder end of the alimentary canal.



BRISTLY MILLIPEDE, *Polyxenus* (enlarged).

Millipedes are divided into two subclasses, Pselaphognatha and Chilognatha. The former, with the single family *Polyxenidæ*, contains minute, rather soft-bodied forms, only about one-tenth of an inch in length, in which the body is composed of nine segments and bears thirteen pairs of legs. The head and dorsal plates are furnished with transverse rows of remarkably formed somewhat scale-like hairs, and there is a great tuft of similar hairs upon the sides of each segment, while the last joint is furnished with a backwardly projecting tubular brush of straight bristles. The antennæ are eight-jointed, and there are no thick glands. These minute creatures live beneath stones or the bark of trees. A species of the typical *Polyxenus* is shown in the illustration. In the Chilognatha

the antennæ are seven-jointed, and the body is not furnished with tufts of scale-like hairs. The group is divisible into the orders Oniscomorpha, Limacomorpha, and Helminthomorpha. In the former, as represented by the pill-millipedes, the body is short and broad, convex above and flat below, with the second and last segments enormously enlarged, and capable of being rolled up into a ball. The skeletal pieces which compose the segments are distinct and movably jointed together. Each typical segment consists of seven pieces; a large and vaulted tergum forming the upper surface and concealing the legs; while beneath this on each side there is a small pleural piece, and between this and the two legs two still smaller tracheal plates bearing the stigmata. The legs are in contact in the middle line of the body, and those of the last pair are enlarged in the male and transformed into a pair of clasping organs. Of the two families into which the order is divided the *Glomeridæ*, or small pill-millipedes of Europe, have the antennæ close together upon the front of the head the eyes with a single row of ocelli, and the body consists of only twelve segments. In the *Zephroniidæ*, or large tropical pill-millipedes, the antennæ are situated on the sides of the head, the eyes are composed of a spherical cluster of ocelli, and the body consists of thirteen segments. In the South African genus *Sphærotherium* the last pair of legs in the male is furnished with a well developed stridulating apparatus, consisting of a finely ridged plate, which by being rubbed against a set of granules on the inner surface of the last tergal shield, gives rise to an audible sound. Although no representatives occur in America, the order is spread over the Eastern Hemisphere, the *Glomeridæ* ranging over Europe and thence into India and Borneo, while the *Zephroniidæ* occur in South Africa, Madagascar, India, the Malay Peninsula, Australia, and New Zealand.



SUMATRAN PILL-MILLIPEDE, *Sphæropœus* (nat. size).

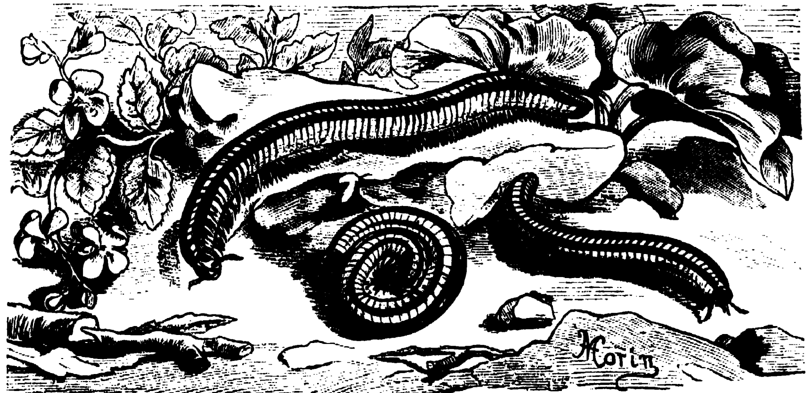


ENGLISH PILL-MILLIPEDE (nat. size).

The Limacomorpha, or slug-like millipedes, form a small group, containing but two known genera and three species included in the family *Glomeridesmidæ*. The body is composed of nineteen or twenty segments, all of them being approximately equal in size and similar in form, and none of them abruptly larger than the rest. The body is capable of being spirally coiled; its segments are formed much as in the Oniscomorpha, but the tracheal plates are not distinct. The last tergal plate, although small, forms a hood which covers over the last pair of legs, and these are modified in form as in the males of the Oniscomorpha. The rest of the legs are composed of only six segments, the basal of which is much enlarged. There are no true eyes. *Glomeridesmus*, the typical genus, is known from two species, found respectively in New Granada and in St. Vincent; the other genus,

Zephroniodesmus, occurring in Sumatra. None of the species exceed a quarter of an inch in length.

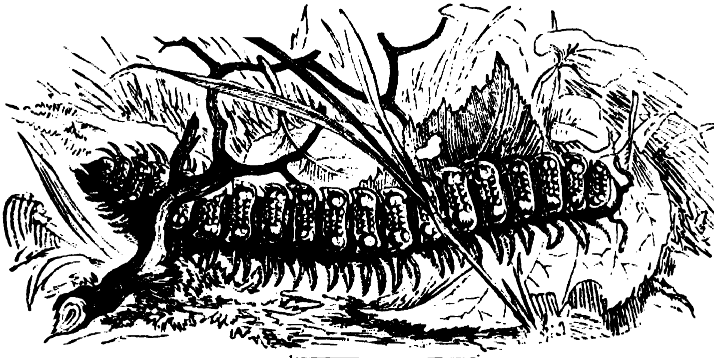
In the Helminthomorpha, or worm-like millipedes, which comprise the majority of the species, the body is composed of from nineteen to over ninety segments, is usually elongate and slender, and capable of being spirally coiled. The characters by which this group may be distinguished from the two preceding are that the last tergal plate forms a complete ring, enclosing the pair of valves and sternum, and that the tracheal plates take the form of two median sternal pieces, to which the legs are directly articulated. Moreover, the pleural scutes, although sometimes free, are less distinct than in the preceding groups. The order is divided into the suborders Colobognatha, Chordeumoidea, Callipodoidea, Iuloidea, and Polydesmoidea. In the first of these the mandibles have undergone great degeneration, and in the most modified forms (*Siphonophora*), the lower edge of the head (labrum) and the lower lip (gnathochilarium) are together produced into a long, piercing snout. The pedal laminæ, or sterna, are always free and movable, as are rarely the pleuræ. The secreting pores are present on all the segments, with the exception of the first four and the last; the parts of the segments around the pores being sometimes produced into wide plate- or rod-like processes covering the legs. The body segments vary in number from about thirty to over seventy, although the largest members of this group seldom exceed an inch in length, and are generally shorter. These millipedes occur in the tropical countries of both hemispheres, one form (*Polyzonium germanicum*) extending into Central Europe. In the Chordeumoidea there are no excretory pores, but each segment bears six symmetrically-arranged bristles. There are usually either thirty or thirty-two body segments; the pedal laminæ are always free, and often the tergal plate is keeled, or furnished with a large lateral process on each side. There is a pair of eyes on the head, and the jaws are normally developed.



MILLIPEDE, *Iulus sabulosus* (enlarged twice).

The Iuloidea, which is the largest suborder of the worm-like millipedes, contains families which may be distinguished from the last group by having the pedal laminæ united to the terga. Some of the tropical species reach 6 inches or more in length, and are the largest millipedes. Of the families, the *Spirostreptidæ* are spread over all tropical countries, but scarcely migrate into temperate climes; while the *Iulidæ* reach their maximum development in Europe and the United States, and are only sparsely represented in the Tropics. The *Cambalidæ* are remarkable for the presence of crests and tubercles on their segments.

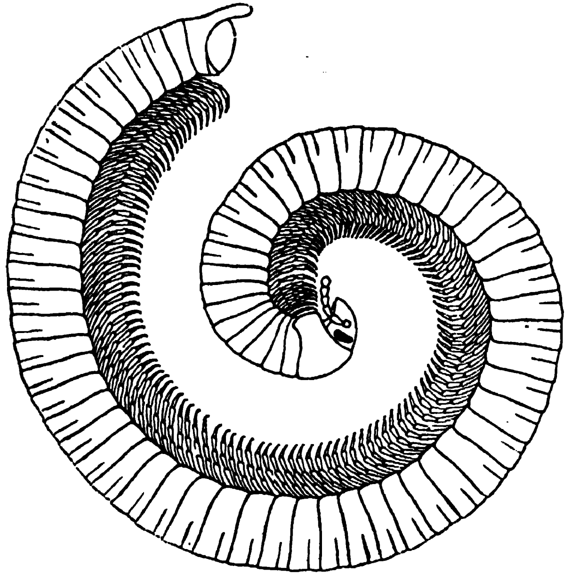
The suborder Polydesmoidea is almost as extensive as the Iuloidea, its members being spread over the habitable world. The largest species belonging to the genus *Platyrrhachus*, which reach a length of several inches, occur in Tropical America and the East Indies. In all, the number of segments is nineteen or twenty, or the fewest amongst the Helminthomorpha. Eyes are wanting, and, as in the Iuloidea, the segments form solid rings, owing to the fusion of the pleuræ and pedal laminæ with the terga. Secreting pores are generally present on most of the segments, though sometimes absent in members of the family *Cryptodesmidæ*. When present, they are almost always borne upon large plate-like processes, springing from the sides of the segments. In distribution this suborder is cosmopolitan, the temperate forms being of small size, while some of the tropical species are large and beautifully coloured.



FLAT MILLIPEDE, *Polydesmus complanatus* (much enlarged).

In habits all millipedes seem to be very similar. Although mostly vegetarians, feeding on soft roots, fruits, and succulent plants, one of the smaller kinds of *Iulidæ* eats worms and decaying animal matter. They occur under stones, logs of wood, or in rotten tree trunks in damp places; and in tropical countries come out in numbers after rain, when they may be seen crawling over the ground and climbing bushes. Moisture is necessary for their existence, and in captivity they freely drink water or milk. Most are slow in their movements, and never trust in speed to escape. When walking the body is kept fully extended, and propelled by the legs, the movements of which resemble a series of waves passing up the body from behind forwards. As already stated, many forms are devoid of eyes; but even those possessing well-developed visual organs appear scarcely able to do more than distinguish light from darkness. As they crawl along, every inch of the road is first carefully touched by the antennæ, which are tipped with a sensory organ, and the creatures appear to be unaware of the presence of an obstacle until the antennæ have actually come into contact with it. All millipedes are perfectly harmless, and may be handled with impunity; but those species possessing odoriferous glands emit a disagreeable odour, due to the secretion of a fluid containing prussic acid. This, no doubt, serves as a protection against birds, ants, etc., to these otherwise defenceless creatures. Some birds will, however, eat them; and in a hornbill's nest in the British Museum the plaster used to block the entrance is largely composed of crushed fragments of a large *Spirostreptus*. Many of the species which have no glands are otherwise protected. *Polyxenus*, for instance, is studded with bristles; while the Oniscomorpha roll themselves up into a round ball, with nothing but the horny integuments exposed. In the breeding-season the females of several forms make earthen nests for their eggs, working the lumps

together. The pill-millipede (*Glomeris*) is said to encase only a few eggs in a ball of earth; while *Iulus* lays from sixty to a hundred in her nest before closing the aperture. Among the suctorial millipedes it is said that the common European *Polyzonium germanicum* coils round her cluster of eggs and stays by them until they are hatched. When hatched, the young are minute, pale-coloured creatures, consisting of the head, with its antennæ and jaws, and six body segments, of which the first three are provided with a pair of legs apiece. During growth the rest of the segments are gradually added between the fifth and sixth, the latter remaining the terminal segment. Growth is also accompanied by moulting.



MILLIPEDE OF THE GENUS *Spirostreptus*, from Celebes.

Remains of extinct millipedes, referable to several of the existing families, occur in the middle Tertiary rocks, while one species of doubtful position has been discovered in the Cretaceous. In the Carboniferous and Devonian rocks a number of types apparently referable to the millipedes occur, although they have been assigned to a special order. From the existing forms they differ by the incompleteness of the union between the dorsal elements of each double segment.

Allied to the millipedes in many characters, but differing in certain special features, is the small group known as Pauropoda. These contain some minute creatures, found in earth and rubbish heaps in Europe and North America, and remarkable for the fact that their antennæ are branched at the apex, and furnished with long bristles. These have twelve body segments, and only nine pairs of legs, the first and the last two segments being limbless.

SCORPIONS, SPIDERS, TICKS, ETC,—Class **Arachnida.**

The members of the three classes of Arthropods hitherto considered are characterised by the possession of a distinct head, bearing in front of the mouth a pair of antennæ, and at the sides of the same at least two pairs of appendages, which act solely as jaws. In the scorpions, spiders, and their allies, on the other hand, there is no such distinct head, while antennæ are wanting; the first pair of appendages being composed of two or three segments only, and acting as seizing or biting organs. These mandibles are, in fact, the only limbs that can be described as jaws. It is true that the basal segments of the second, and sometimes of the third and fourth, pairs of limbs are used for crushing prey; but their remaining segments nearly always form leg-like appendages, used both for locomotion and grasping. In scorpions, for instance, the limbs of the second pair are

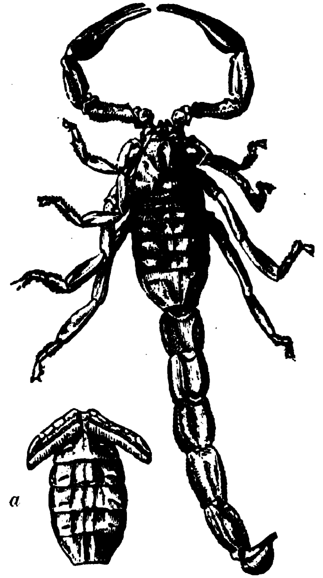
converted into large pincers; while in spiders they are short, and resemble the other limbs. In scorpions and the other groups, where these limbs form prehensile weapons, they are called *chelæ*; whereas in the spiders and ticks, where they are smaller and tactile in nature, they are known as *palpi*. Behind the palpi or chelæ come four pairs of limbs, acting as the locomotor organs. The palpi or chelæ are typically composed of six segments, and armed with a single claw, which, however, may be fused with the terminal segment, as in scorpions. The legs seem primarily to have been six-jointed; and their segments, from base to apex, are respectively termed coxa, trochanter, femur, patella, tibia, tarsus. One or more of these is, however, almost invariably divided, so that the number rises to at least seven. Thus, whereas in the scorpions the tibia, and in spiders the tarsus, is divided, in other groups, like the Pedipalpi, the tarsus may be composed of a number of small segments. Accordingly, six pairs of large appendages are attached to the forepart of the body; and since this part was supposed to represent the combined head and thorax of insects, it is termed the cephalothorax. The abdomen may bear small, dwarfed limbs, as in scorpions and spiders, but its limbs are never, either structurally or functionally, like those of the cephalothorax. Although it may be undivided, this part never contains more than twelve segments, and often much fewer. Allowing twelve to the abdomen, and six to the cephalothorax, the body of the more typical members of the class comprises eighteen segments. All Arachnoids breathe air, either by means of short sacs or of long tracheal tubes communicating with the exterior by apertures (*stigmata*) on the lower surface of some of the abdominal segments. The young which, save in scorpions, are born in the egg stage, resemble their parents, and in the course of growth only undergo a series of moults without metamorphosis. The class may be divided into eight orders, the first of which includes

The Scorpions,—Order Scorpiones.

In this group all the typical eighteen segments of the body are developed, although the last five are abruptly narrowed to form with the telson, or poison-sting, the tail. The whole abdomen, including the tail, is distinctly jointed; but the cephalothorax is covered above with a single plate, or carapace, bearing the eyes. The latter vary from six to ten, two being placed together in the middle, and the others arranged at the sides of the forepart of the carapace. Of the appendages, the four hinder pairs are similar, being tipped with a pair of claws, and used for locomotion. The two front pairs, however, have been transformed into pincers or nippers, the first pair, or mandibles, being small and three-jointed, and the second, the chelæ, or great pincers, of large size and six-jointed. The coxæ of the four pairs of legs are immovably united to form the floor of the cephalothorax, and wedged in between those of the last two pairs there is a single sternal plate, the shape of which is of considerable value as a character in the classification of these animals. The breathing-organs consist of four pairs of sacs,—of which the cavities are filled up with a number of fine plates, arranged like the leaves of a book,—are placed upon the third, fourth, fifth, and sixth segments of the abdomen, and their apertures open upon the sternal or ventral plates of these segments.

In addition to these stigmata, the abdomen bears a pair of curious organs called combs, or pectines, which are placed upon the lower surface of the second segment, and are very characteristic of the group.

Scorpions are found almost all over the world to the south of the 40th or 45th parallel of north latitude, the only extensive area of land in the Southern Hemisphere in which they do not occur being New Zealand. The largest known forms occur in the tropical parts of Africa, especially on the shores of the Gulf of Guinea, and in the southern districts of India. These are the big black scorpions belonging to the genus *Scorpio*, which may attain a length of 8 or 9 inches, measured from the front of the head to the end of the tail. In structure the various species and genera are, on the whole, surprisingly uniform, all the known forms being referable to four families, namely, the *Buthidæ*, *Bothriuridæ*, *Iuridæ*, and *Scorpionidæ*. In the *Buthidæ* the sternum of the cephalothorax is small and triangularly-pointed in front, in the *Bothriuridæ* it is transversely linear, and in the others it is broad and pentagonal; but while the *Iuridæ* agree with the other two families in possessing two spurs on the articular membrane of the tarsus, the *Scorpionidæ* have but one.

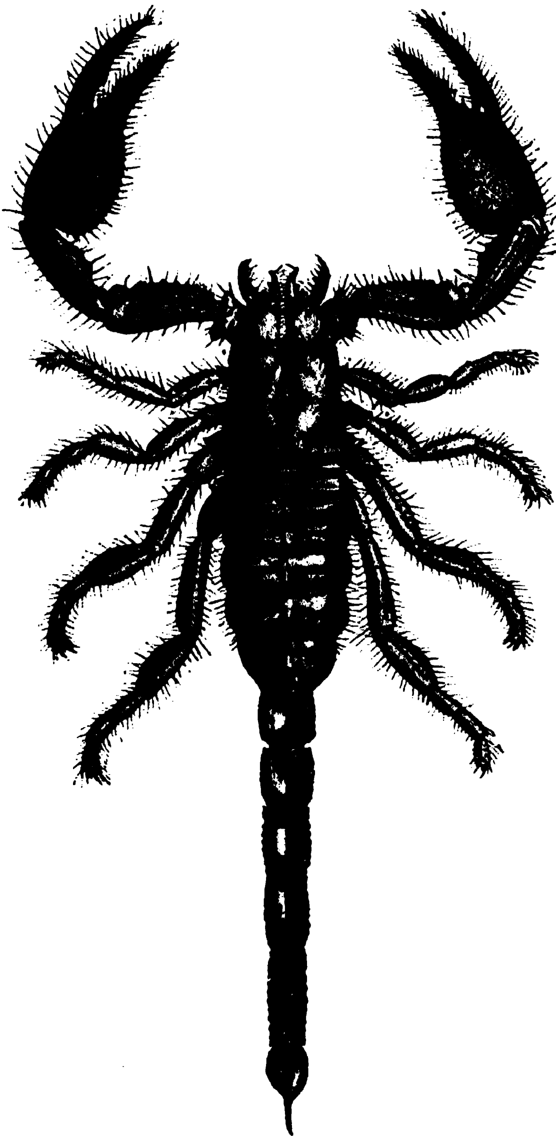


SPANISH YELLOW SCORPION, *Buthus europæus* (nat. size).
a, Lower surface of the abdomen, showing combs and stigmata.

Scorpions are a very ancient group, well-preserved remains of two genera having been discovered in the upper Silurian beds of both Europe and North America. In the Carboniferous period, too, they were evidently abundant; but no fossil forms have yet been discovered in rocks of Secondary age, and only one has been recorded from Tertiary strata, this having been discovered in the amber beds of the Baltic. The strangest fact however, connected with fossil scorpions is the small amount of change the group has undergone, in spite of the enormous time that it has been in existence. For instance, the Tertiary species named *Tityus eocænus* does not differ in any important particulars from existing forms; while those from the Carboniferous can only be distinguished from them as a group by having the median eyes on the carapace in advance of the lateral. In this feature they agree with the Silurian species; but the latter, of which *Palæophonus* is the best known, are unique in the entire group in having the feet tipped with a single claw. For this reason the order, including living and extinct species, has been divided into two sections, the Apoxypodes, or those with pointed feet, including the Silurian *Palæophonus*, and the Dionychopodes, or those in which the feet are tipped with a pair of movable claws. This last group is again divisible into the Anthracoscorpii, or scorpions of the Coal period, in which the median eyes are in front of the lateral, and the Neoscorpii, or recent forms, in which the median eyes are placed further back.

In habits the different species seem to vary but little, most of them being nocturnal and all of them exclusively carnivorous, feeding upon any living creature, weak enough to be overpowered. They seem, however, to be largely dependent

upon chance for the capture of prey; for although provided with a large number of eyes, vision is so defective that they cannot see more than a few inches, and there is no evidence of the existence of any organs of hearing. The sense of touch, however, which resides in the hairs with which the body and limbs are studded, is exceedingly keen. No sooner does an unwary insect approach within reach than it is seized in the vice-like grip of the scorpion's pincers; then quick as lightning the tail is brought into use, and the sting plunged into the struggling prey, which, as a rule, quickly succumbs to the paralysing effect of the poison. If, however, the prey be of large size, and muscular in proportion, the process of stinging is repeated; but it has been noticed that the scorpion in most cases carefully selects a soft spot into which to thrust its weapon, and does not strike at random. The object of this caution is evidently to avoid all risk of breaking the point of the sting against too hard a substance. The same care is shown in the carriage of the tail, this organ when not in use being almost always kept curled up in such a manner that the sting is securely protected. Having imperfectly developed visionary powers, and no tactile antennæ to supply this deficiency, scorpions when on the move always hold their large pincers well to the front, so as carefully to feel the way. But different species show considerable variation in the carriage of the body, some like *Buthus*, holding it high, while others shuffle along scarcely lifting it off the ground.



AFRICAN ROCK-SCORPION, *Scorpio viatoris* (nat size).

Again, many of the larger species, such as those belonging to *Scorpio* and *Opisthophthalmus*, live in deep holes, which they excavate in the ground by means of their large and powerful pincers. Others, like the little flat scorpions of South Europe (*Euscorpius*), hide away under stones and tree trunks, to which they cling belly uppermost; whilst others, like *Buthus*, dig shallow pits in sand, just deep enough to allow their eyes a clear vision of their surround-

ings, with the back on a level with the surface of the soil, and here concealed from view they lurk on the look out for prey. Sound-producing organs have been found in the large, black rock-scorpions of India and Africa; the organ, which lies between the basal segment of the pincers and that of the first pair of legs, consists of a set of tubercles and of a cluster of curved hair-tipped spines. When the scorpions are excited, they wave their pincers up and down, and by thus scraping the spinules against the tubercles emit a rustling sound, which has been compared to that produced by rubbing a stiff tooth-brush with one's finger nails. This organ is equally well developed in members of both sexes, and probably serves as a warning to enemies to keep their distance. An analogous organ is found in the South African *Opisthophthalmus*, but in this case it consists of leaf-like hairs placed on the inner surface of the mandibles.

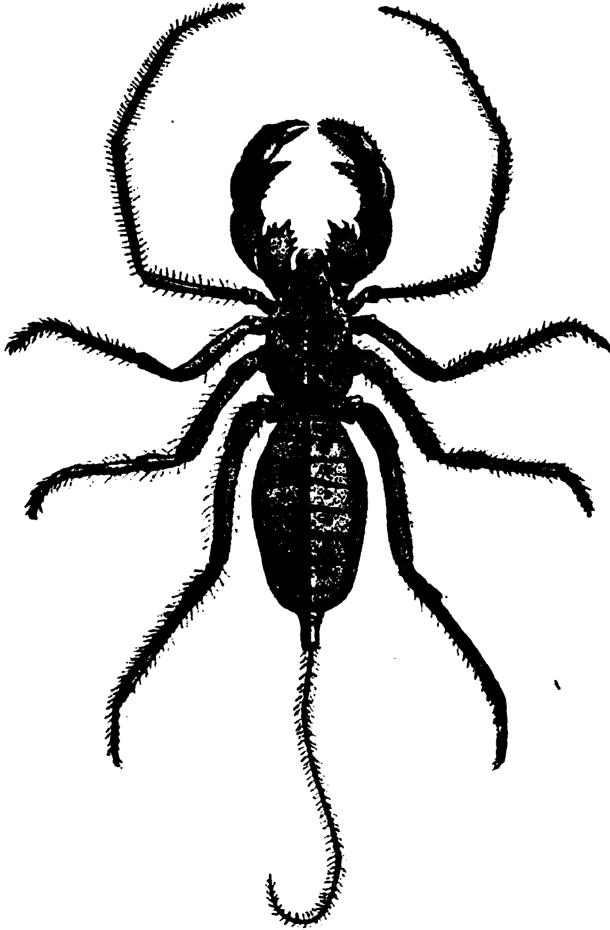
THE WHIP-SCORPIONS AND THEIR ALLIES,—Order PEDIPALPI.

The members of the second order of the Arachnida resemble the scorpions in having the abdomen composed of twelve segments, and the second pair of appendages transformed into huge seizing organs, but differ from them in a number of important characters. The legs of the first pair, for instance, are not used for locomotion, but only as organs of touch, and have their last segment devoid of claws and divided into a series of secondary segments. Moreover, in the rest of the legs the feet are three-jointed. The most marked distinctions are, however, found in the abdomen. In the first place, this region is sharply marked off from the cephalothorax by a deep constriction forming a narrow waist. There is no trace of combs, and the first sternal plate is of large size, and entirely covers the ventral region of the first and second segments; so that, although there are twelve dorsal plates on this region of the body, there are only eleven sternal plates. The breathing-organs are of the same nature as those of the scorpions, namely, lung-books; but instead of forming four pairs, situated upon the third, fourth, fifth, and sixth sterna, there are only two pairs, of which the apertures are placed behind the sterna of the second and third segments. The order is divided into a tailed group (Uropygi), and a tailless group (Amblypygi). In the former the body is elongate, both cephalothorax and abdomen being much longer than wide; and to the last segment of the abdomen there is attached a movable tail corresponding to the sting of the scorpions. On the lower side of the cephalothorax there are two distinct sternal pieces, an anterior and a posterior, the latter being triangular and lying between the coxæ of the last pair of legs, while the anterior is longer and placed between the coxæ of the first pair of legs and behind those of the pincers, which are united to form a kind of lower lip. The area between these sternal plates is narrow, membranous, and largely encroached upon by the coxæ of the second and third legs, which nearly or quite meet in the middle line. The legs of the first pair are also much shorter, and more typically leg-like than in the Amblypygi, the tarsal segment alone being divided into a series of nine cylindrical secondary segments.

Tailed Group.

The tailed suborder may be further divided into the sections *Tartarides* and *Oxopæi*. The former is a small group in which the

cephalothorax is divided into two regions by the jointing of the carapace, the region which corresponds to the posterior two pairs of legs having a small but distinct tergal plate of its own. Moreover, the eyes are either absent or reduced to a single pair, and the tail-piece, which is jointed to the last segment of the abdomen, is short and undivided. There is a single family of this tribe, the *Schizonotidæ*, so-called on account of the jointing of the carapace. The family contains two genera, *Schizonotus* and *Tripeltis*, the species of which are pale-coloured forms, less than quarter of an inch in length, and confined to Burma and Ceylon.



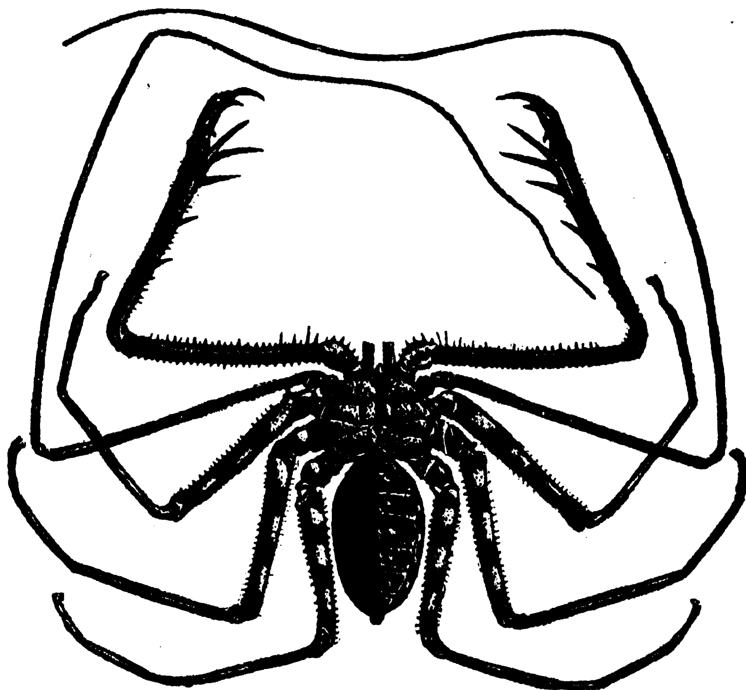
FEMALE OF BORNEAN WHIP-SCORPION, *Thelyphonus hosei* (nat. size).

The term *Oxopœi*, or acid-producers, is applied to the family *Thelyphonidæ*, or whip-scorpions, which differ from the last in having the carapace undivided, and the tail long, thread-like, and many jointed. The last three segments of the abdomen, too, are very narrow, forming a movable stalk for the filiform tail, and on its last segment there are generally two, sometimes four, clear yellow spots, the *ommatoids*. The eyes are always well developed, two of them being situated close to the front edge of the carapace, and the others, of which there are eight or ten, arranged in two clusters of three or five each at the sides of the head, some distance behind the front eyes. The adult males differ from the females in having longer and often differently shaped pincers, and also very generally in having the first ventral plate of the abdomen larger and more swollen. The females of some genera (*Thelyphonus*, *Typopeltis*), on the other hand, have the segments of the tarsus of the first pair of legs peculiarly modified.

Considering their antiquity and wide range, the whip-scorpions are strikingly uniform in structure. The largest specimens, measuring about 4 inches in length, have been met with in North-East India and Central and South America. All the species seem to be nocturnal, spending the day hiding beneath stones, logs of wood, etc., and, when surprised, hurrying away with considerable speed into any holes or crevices that are handy. The Indian species require moist surroundings,

being generally only found during the heaviest rains, and soon dying when removed from their humid haunts. In Florida there is, however, a species frequenting dry sandy localities; and some species dig burrows in the ground and use them as permanent places of abode.

Tailless Group. In the tailless group, or Amblypygi, the body is much flattened, the carapace being wider than long, and kidney-shaped, and the abdomen oval with the segments gradually decreasing in size in front and behind, and none at the hinder end being narrowed to form a stalk. Corresponding with the great width of the carapace, we find the coxæ of the third and fourth pairs of legs widely separated, so that there is an oval sternal area, around which the coxæ of the five pairs of large cephalothoracic limbs are arranged radially. The anterior



A WEST AFRICAN TAILLESS WHIP-SCORPION, *Titanodamen johnstoni* (nat. size).

and posterior sternal pieces of the preceding suborder are present between the coxæ of the first and last pair of legs respectively, and the space between them is filled by horny pieces, varying in the degree of their development. The appendages also differ from those of the Uropygi, the basal segments of the pincers being freely movable and not united together, while these appendages are longer, thinner, and very spiny. The terminal segment forms a sharp claw, closing back on the penultimate segment like the blade of a knife. The legs of the first pair are long and slender, and all its segments, except the first three, are converted into a long, thread-like, many-jointed lash acting as a feeler. The males do not as a rule differ strikingly in external characters from the females; although the abdomen is narrower, and the pincers and legs are longer.

In geographical distribution the group resembles the *Thelyphonidæ*, with the

exception that it is spread over Africa south of the Sahara, extending from Senegambia and Abyssinia southwards into Cape Colony; but there are no species from Madagascar. It also seems to extend in India farther to the west than do the *Thelyphonidæ*, since species occur at Bombay, and thence spread along the south coast of Arabia from Muscat to Aden. In the Indian region the species are not so numerous as the true whip-scorpions, and in the Philippines they seem confined to caves, living permanently in the dark. None are known from Japan or China; but in America a few have been recorded from Texas and California, and many from Central America, the West Indies, and South America, as far down as Patagonia. Like the last, this group dates back to the Carboniferous, a single genus, *Graeophonus*, having been described from the coal-measures of North America. A single specimen has also been discovered in the Miocene gypsum beds of Aix. The existing forms may be all included in the family *Tarantulidæ*; the genera being mainly characterised by the degree of development of the horny pieces on the lower surface of the cephalothorax. In habits the group resembles the last, except that the species, instead of digging burrows, avail themselves of natural crevices and holes, hiding beneath stones or fallen tree trunks, for which they are adapted by the flatness of their bodies. The species frequenting grottoes in the Philippines cling to the walls, with legs extended, and dart into rocky fissures at the least disturbance.

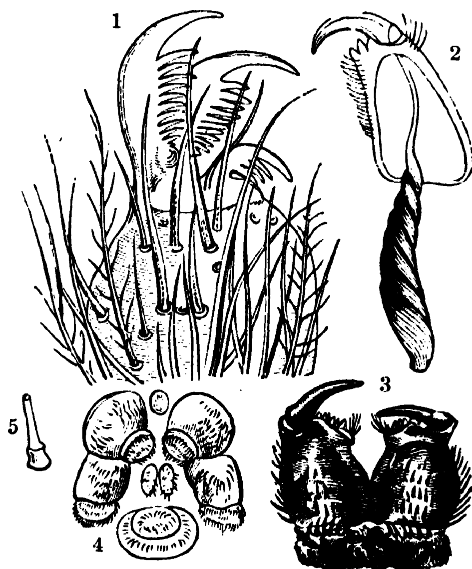
Order PALPIGRADI.

This group is represented only by a single South European form (*Kœnenia mirabilis*). Structurally, this minute creature occupies a position intermediate between the whip-scorpions and the *Solifugæ*. As in the *Thelyphonidæ*, there is a long, jointed tail, articulated to the last abdominal segment, which, with the two that precede it, is narrowed to form a movable stalk; but, as in the *Solifugæ*, the abdomen consists of only ten segments. The carapace is segmented and has no eyes; but in the structure of its appendages *Kœnenia* is peculiar. The mandibles are large, pincer-like, and composed of three segments, but the palpi and all the legs are alike, being long, slender, and composed of a number of segments. The legs of the first pair, however, are the longest, as in the Pedipalpi.

THE TRUE OR WEB-SPIDERS,—Order ARANEÆ.

In many points of their organisation, the true spiders approach the tailless Pedipalpi. They have, for instance, a deep waist, separating the cephalothorax and the abdomen; the limbs are arranged radially round the cephalothorax, which is covered below by a single sternal plate, to which a labial piece is united in front, and above by a carapace bearing, in the majority of cases, eight eyes. Moreover, in some instances, there are four pairs of lung-sacs, as in the Pedipalpi, although generally the hinder pair are replaced by tracheal tubes. The differences between the two orders are, however, striking enough. Thus the four pairs of legs are alike, being composed of seven segments, and used for locomotion; while there are no great seizing limbs, the appendages of the second pair being short and leg-like, though composed of but six segments; of these the basal is termed the *maxilla*, on

account of its function as a jaw, and the remaining five the *palpus*. The mandibles, too, are larger than in the Pedipalpi, and contain a poison-gland, opening at the tip of the second segment, which is transformed into a strong fang. In the abdomen, a marked character of most spiders is the absence of segmentation, its covering consisting of a soft, hairy integument, or a hard horny cuticle, while on its lower surface there are two pairs of shortened appendages, called the *spinning mammillæ*, upon which open the silk-glands. These mammillæ are perhaps the most distinctive feature in spiders. Although varying considerably in shape and length, they are usually short and composed of two, or rarely three, segments. Each spinning appendage, however, is primarily composed of two branches, an outer and an inner, the outer forming the two- or three-jointed mammilla, while the inner branch or intermediate mammilla is always one-jointed. Consequently there may be as many as eight mammillæ; usually, however, there are but six, owing to the disappearance of the inner branches of the first pair of spinning appendages.

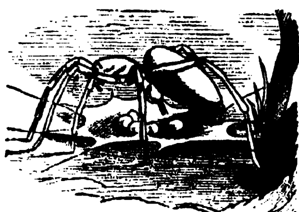


ANATOMY OF COMMON CROSS SPIDER (*Araneus diadema*).
1, Foot with claws and hairs; 2, Mandible with poison-gland and duct; 3, Face and jaws; 4, Spinning mammillæ; 5, One of the spinning papillæ.

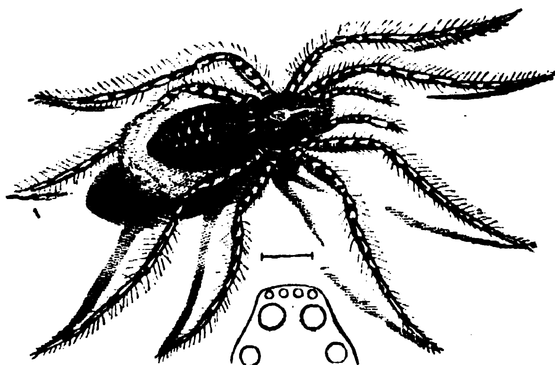
The oldest known form (*Arthrolycosa*) of the Carboniferous, differs from nearly all existing forms in having the abdomen protected above by a series of plates, as in the recent genus *Liphistius*, to which it was doubtless allied. In Tertiary times, spiders closely related to those now existing were abundantly distributed over the Northern Hemisphere, as their well preserved remains from the Oligocene amber beds of the Baltic and from the gypsum beds of Aix satisfactorily testify.

The females of all spiders lay eggs, from which the young are subsequently hatched. The first act of the mother before laying, is to spin a small and often saucer-shaped web. In this the eggs are deposited, and are then covered over with two layers of silk forming a cocoon. The cocoons differ greatly in shape and colour and texture, according to the spider that makes them. They may be green, yellow, white, mottled, or nearly black; round, oval, lenticular, or cigar-shaped; soft and woolly, hard and nut-like, or smooth like parchment; while the outer casing is sometimes caked with earth or other foreign material for purposes of concealment. After the construction of the cocoon, the mother's interest in its fate varies in different spiders. Sometimes she pays no further attention to it, as in the case of the garden spider (*Araneus*), which suspends it in or near her web, and leaves the young to shift for themselves. In some cases, again, she remains for a longer or shorter time on guard in its vicinity, sometimes spinning a regular nest for her young and herself during this period of quiescence; but in other cases, especially among the wandering species,

the mother carries the cocoon about with her, either attached to her spinners or clasped between her jaws. The young hatch inside the cocoon, and subsequently make their way to the outer world through a rupture in its walls. They appear in a helpless state, either clinging together in clusters, as in the *Argiopidæ*; staying in the nest, as in the jumping spiders; or clambering on to their mother's back, as in the wolf-spiders. During growth the skin is periodically cast, the membrane of the cephalothorax splitting above the base of the limbs, and the carapace being raised to make an aperture, through which the body with the new skin emerges. The young spider is then soft, limp, and at the mercy of its enemies, until the integument becomes sufficiently hard and resisting to afford firm support to the muscles. Consequently, during this time, many species seek shelter in silken tubes spun for the purpose. On an average, perhaps, spiders undergo about eight or ten moults before reaching maturity, which is attained during the period intervening between the last moult and the last but one, so that the males and females, which during growth are much alike, emerge from the final casting in a fully developed state. In this stage the two sexes are distinguishable, the female having the palpi normally constructed, while in the male the terminal segment of this appendage carries on its lower surface an organ which in its simplest form is somewhat flask-shaped, but is more often variously modified and complicated. The male, also, is generally rather the smaller of the two, sometimes indeed, as in many tropical members of the family *Argiopidæ*, being of quite insignificant size in comparison with the female. He also has longer legs and a thinner abdomen, being thus the more graceful and active of the two. In the most sedentary of all spiders, or those belonging to the families *Theridiidæ* and *Argiopidæ*, still more striking differences often occur, the front part of the carapace being sometimes raised into a high pinnacle-like outgrowth. When the two sexes are approximately equal in size, the male is comparatively safe from his spouse during the period of courtship, but when, as in the *Argiopidæ*, he is much the weaker of the two, the female often avails herself of her superiority in size and strength to devour her mate. The first uses of the silk-glands seem to be to supply material for the construction of the cocoon, and of a tent or tubular retreat for the protection of the mother and young, or for the latter when passing through the dangers attendant upon the casting of the skin. Such cases are also used for the same purpose by many species during the winter months in temperate latitudes, and during drought in more tropical climes. It thus appears that, in the first

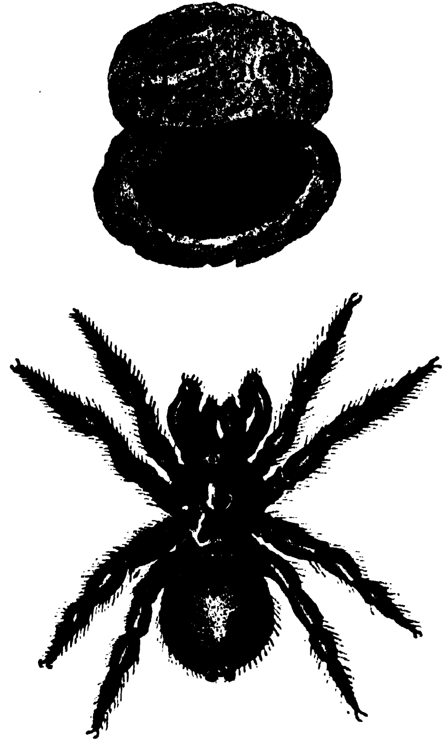


FEMALE OF *Drassus* LAYING HER EGGS.



FEMALE OF WOLF-SPIDER (*Pardosa amentata*) CARRYING HER COCOON.
Below is shown the arrangement of the eyes when seen from above.

instance, the spinning instincts were directed solely to the protection of the species during infancy, growth, and maturity; and we may conclude that, apart from the cocoon, the initial stage in the development of web-making was the formation of some kind of tubular retreat. From this point the evolution of the spinning industry—perhaps the most important and interesting feature in the natural history of spiders—seems to have progressed along two lines. Along one the tubular retreat becomes gradually elaborated until it culminates in the trap-door nest; while along the other the tube is to a greater or less extent, or even wholly, superseded by a new structure, the snare; the latter attaining its greatest perfection in the triangular snap-net of *Hyptiotes*, or the beautiful and symmetrical orb-web of the common garden spider. At the outset it is possible that the simplest form of snare arose from the spinning of supporting lines around the mouth of the tubular retreat, and if these served to entangle prey it is clear that a new and easy method of obtaining food would be opened up, and the habit of spinning webs of this nature would be fostered until the various kinds of nets became evolved. Another use to which the spinning of threads may be put is that of flying. This is especially practised by young spiders, who on fine autumnal days climb to the tops of bushes and fences, and, raising the abdomen into the air, emit a thread or tuft of threads which blowing away in the wind soon become large and strong enough to carry the spider, sometimes to great heights above the ground. It was originally supposed that these threads were spun by a species called the gossamer-spider, but it is now known that the habit is practised by young spiders of different families. Floating about in the air, these fine threads meet and, becoming entangled, form masses of web, which ultimately fall upon the bushes and fields, sometimes covering them thickly with a white coating of fine silk.



JAMAICA TRAP-DOOR SPIDER (*Pachylomerus*) AND APERTURE OF ITS NEST.

SEGMENTED GROUP,—Suborder **Mesothelæ**.

Spiders may be divided into the two main groups, *Mesothelæ* and *Opisthothelæ*. In the former, the spinning mammillæ, eight in number, are situated in a cluster in the middle of the lower surface of the abdomen; the upper surface of the latter being covered with a series of nine dorsal plates, resembling those of scorpions, while its lower surface is similarly furnished with two sternal plates covering the first and second pairs of lung-sacs. In these characters the group differs from other spiders, and in having the abdomen segmented it constitutes a kind of link

between them and the tailless Pedipalpi. It likewise resembles the latter in the structure and situation of the breathing-organs, and also in the mode in which the mandibles are articulated to the cephalothorax; their basal segments being directed forwards, parallel to each other and the long axis of the body, while the second segments or fangs are directed backwards, also nearly parallel to the longitudinal axis. The eight eyes are situated on a tubercle close to the front edge of the flat and broad carapace; the median being small, and the lateral larger and placed in a semicircle on each side. The long and powerful legs are armed with spines, and tipped with three claws; their coxæ being long, whereas those of the palpi have no long maxillary process as in most other spiders. This group comprises only the family *Liphistiidæ*, with the genus *Liphistius*, of which there is one species from Penang, and another from Sumatra; both of large size, measuring about 2 inches in length. Nothing is known of their habits.

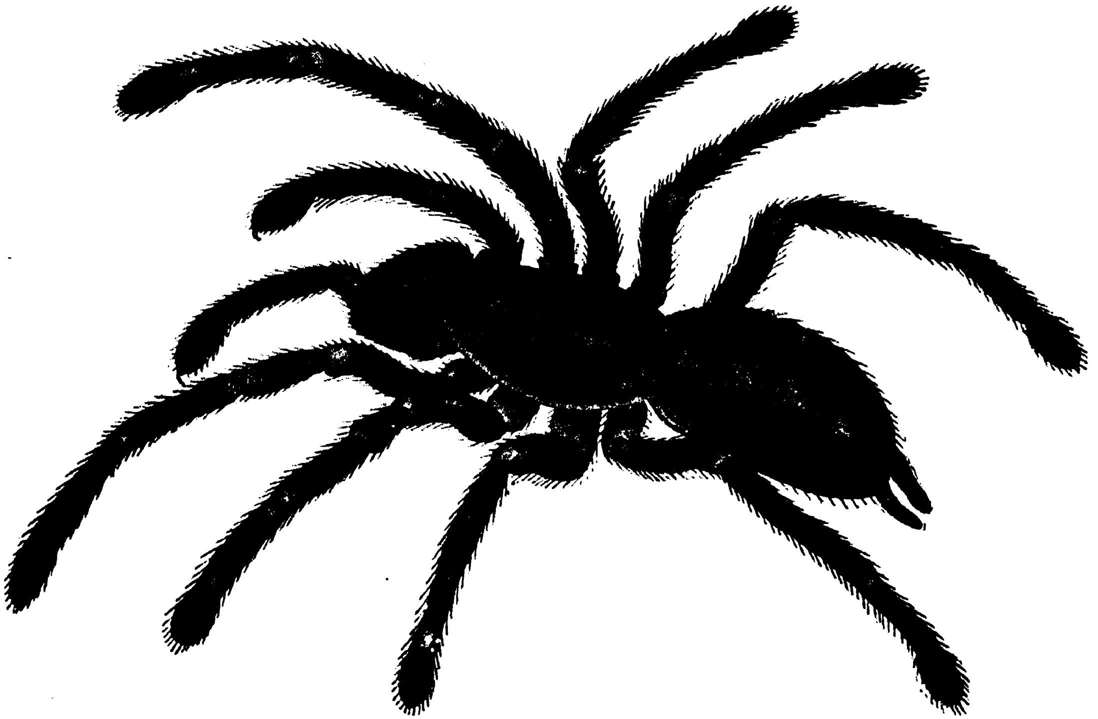
TYPICAL GROUP,—Suborder **Opisthothelæ**.

In this group the abdomen is not segmented, and the spinning mammillæ—of which there are never more than six, owing to the disappearance or fusion of the inner branches of the first pair of appendages—have moved to the hinder extremity of the abdomen. It is separable into the sections *Mygalomorphæ* and *Arachnomorphæ*. The former group includes the forms making the nearest approach to the preceding suborder. The spinning mammillæ are reduced in number, being usually only four, owing to the disappearance of the anterior pair of appendages, the posterior pair alone remaining, and being represented on each side by a long external jointed branch and a short inner one-jointed branch. Sometimes, however, two mammillæ of the front pair are retained. The eyes generally form a compact group but the lateral eyes on each side may be widely separated from the median pair.

Several families, passing almost imperceptibly into one another, are comprised in the group. Among these, the bird-catching spiders (*Theraphosidæ*) are the giants of the order. They include several genera, such as *Avicularia* and *Pœcilotheria*; a species of the latter being shown in the illustration on p. 225. Usually they are dark brown or black in colour, and clothed with short hairs mingled with bristles. The lower surfaces of the feet are covered with a thick pad of silky hair, furnished with adhesive power, by means of which these spiders are able to climb vertical sheets of glass. The claws on the feet seem to be of but little service, being small and generally concealed amongst the hairs. There are a large number of species and genera distributed over all tropical and subtropical countries; the largest species occurring in the northern parts of South America, where specimens almost equalling a rat in size are met with. The males are always smaller than the females, being of lighter build, longer in the leg, and consequently more agile. These spiders spin no web for the capture of prey, living either in holes in the ground or beneath stones and silk-lined logs, or in silken tubes which they spin in the hollows or upon the forked branches of trees. At night they issue forth in search of food which for the most part consists of beetles and other insects; but they will destroy and eat any living creature weak

enough to be overpowered, and travellers report having found small birds in their clutches. When laid, the eggs are wrapped in a strong cocoon, which the mother guards in her nest.

The bird-eating spiders inhabiting the countries lying between India and Queensland differ from those coming from Africa and America in possessing sound-producing organs, which lie between the outer surface of the mandible and the inner surface of the maxilla or basal segment of the palp. In one case, namely, in the subfamily *Selenocosmiinæ*, the outer surface of the mandible is furnished with spines, and the inner surface of the maxilla with a set of horny notes, of varying thickness and length, which are thrown into a state of vibration by being

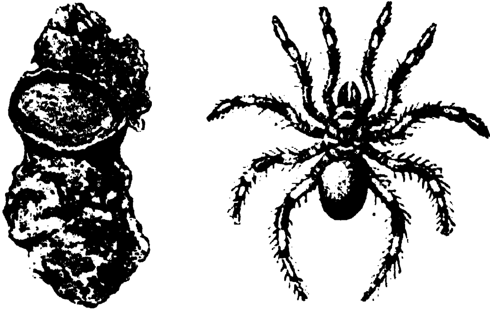


BANDED BIRD-EATING SPIDER (*Pœcilotheria fasciata*).

rubbed over the spikes on the mandible. This organ is equally well developed in both males and females, and appears in the young soon after they emerge from the eggs. When these spiders are irritated or alarmed, they raise themselves upon their hind-legs and, by waving the palpi, scrape the keys against the spines on the mandibles and produce a sound which has been described as resembling the dropping of shot upon a plate. It is probable that the sound thus produced acts for the benefit of the spider in warning other creatures. In the second group (*Ornithoctoninæ*) the notes, formed of feathery hairs, are situated on the outer surface of the mandible, and the spines on the inner surface of the maxilla.

Nearly allied is the family *Dipluridæ*, differing in having three well-developed claws upon the feet, and the external spinning mammillæ exceedingly long. Its members differ in habits, spinning upon the ground wide sheet-like webs to ensnare

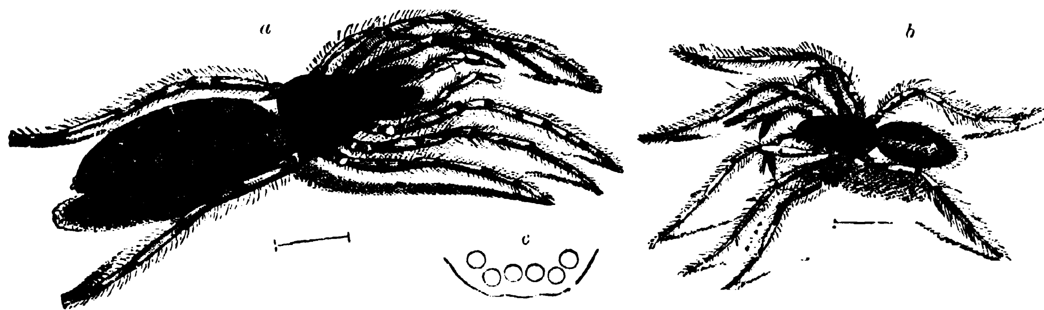
prey. So far as the claw armature of the feet is concerned this family leads on to the trap-door spiders (*Ctenizidæ*), famed for the perfection of their architecture. Although the species exhibit considerable variation in the perfection of their nests, the method of work appears in all cases to be substantially the same. A deep tunnel is first dug in the soil and then lined with silk to prevent the falling in of the loose earth. Then, with the object of excluding enemies such as ants and wasps, as well as to keep out rain, a lid, formed of layers of silk, strengthened with particles of soil, is built over the aperture, and attached along one side to the wall of the tube in such a manner that the elasticity of the silken hinge keeps the door normally closed. The outer surface of the door is then covered, if necessary, with fragments of moss, or with pieces of the plants that grow in the vicinity of the nest, so that when the door is closed it matches its surroundings and becomes practically invisible. In the genus *Nemesia*, from the shores of the Mediterranean and abundant in the Riviera, the lid is thin and light and of the so-called wafer type; but in the majority of cases it is thick and heavy, with a bevelled edge, so that it fits tightly into the upper end of the burrow, and is said to be of the cork-type. Not unfrequently the spider digs a side gallery to this burrow, and shuts the aperture of communication between the two by means of a second door. Then, in cases of emergency, when the lid of the main entrance has been forced, the spider retreats along the second branch and closes the door, so that the enemy, after exploring the main tube and finding it empty, departs, believing the burrow to be tenantless. In some instances, indeed, the secondary branch is made to communicate by a special opening with the exterior, so that even if its internal aperture be discovered, the spider can still beat a retreat. It is by no means, however, an easy matter to force open the lid in the first instance; for no sooner does the spider feel the attempt being made, than it seizes the inner side of the door with the claws of its front-legs, and, firmly planting those of its hinder limbs in the silken walls of the burrow, resists every effort to force an entrance. A few species have forsaken the ground and taken to building their nests upon the trunks of trees, as shown in the figure above. Some of these, like the South African *Moggridgea*, and the Mascarene *Myrtale*, avail themselves of natural irregularities in the surface and build silken tubes in the crevices; then, chipping off pieces of bark and lichen, cover the white silk, so that the tube and its door become invisible. The South American *Pseudidiops*, frequenting palm-trees at Bahia, appears to excavate its own grooves in the bark by means of the fangs, and the stout, short spines with which its mandibles are armed.


PALM TRAP-DOOR SPIDER (*Pseudidiops*) AND ITS NEST (nat. size)

In North Europe the only representative of this group is the genus *Atypus*, which has been found in England and Ireland. This genus belongs to the family *Atypidæ*, differing from the rest of the section in possessing long maxillary processes on the coxæ of the palp; and also in having six spinning mammillæ.

Instead of making a trap-door nest, this spider spins a long silk tube, closed at the ends, one half of which is buried in the earth, while the other lies loosely among the grass or stones on the surface of the ground. When a fly or beetle alights on this part of the web, the spider slowly and cautiously climbs to the spot, and, invisible all the time to the insect, suddenly seizes it from within, and tearing away the web drags its prey through the aperture, which is then repaired.

The next section is that of the *Arachnomorphæ*, which includes the common house and field spiders, and differs from the last in having the basal segment of the mandible vertical instead of horizontal, and the fang closing inwards and backwards. There are generally six spinning mammillæ, comprising an anterior two-jointed pair, a similar posterior pair, and an intermediate single-jointed pair. Between those of the front pair there is either a functionless membranous piece, the *colulus*, or a paired plate, the *cribellum*, which is studded with the apertures of spinning glands. The eyes are occasionally arranged in three clusters, two being in the middle and three close together on each side; but usually the three lateral



FIELD-SPIDERS (*Segestria senoculata*). *a*, Female; *b*, Male; *c*, Arrangement of eyes (enlarged).

ones are scattered, and the eight eyes placed on the front of the head in two rows. The *Arachnomorphæ* are divided according to their structural characteristics and web-making instincts into a number of tribes each containing one or more families. The first tribe, *Umbellitelariæ*, contains the single family *Hypochilidæ*, represented by the genus *Hypochilus* in North America and *Ectatosticta* in China. These two spiders differ from all the rest in having the hinder pair of breathing-organs in the form of lung-sacs; the cribellum and calamistrum being present and the long and slender legs furnished with three claws. In the genus *Hypochilus*, which is found in the forests of Tennessee, the web is constructed beneath overhanging rocks and cliffs and has somewhat the form of an inverted saucer, made of thick white silk and kept in place by a loose network of threads. Beneath this web the spider remains upside down, and it has the habit, common to other species, of violently shaking the web when alarmed. In the tribe *Pseudoterritelariæ*, as in the rest of the section, the breathing-organs of the hinder pair are in the form of tubular tracheæ, but their apertures are widely separated and situated immediately behind those of the front pair. There is no cribellum nor calamistrum, and the eyes are reduced in number, being usually six, but sometimes, as in *Nops*, only two. Two well-known European representatives of this tribe constitute the genera *Dysdera* and *Segestria*. The former, found not

uncommonly under stones in damp places, may be recognised by the coral-red colour of its carapace, its bright yellow legs and pale grey abdomen. It makes no snare, merely constructing a small silken case, which serves as a protection to the mother and her eggs at the breeding-season. *Segestria*, on the contrary, is much darker coloured, with a band of diamond-shaped spots upon the upper side of the abdomen. It spins in holes in old walls a tubular nest, from whose aperture threads which serve to intercept prey pass to surrounding objects. In addition to these forms—which belong to the family *Dysderidæ*—this tribe contains the family *Oonopidæ*, comprising small, slender-legged spiders, with a short and high carapace, and the exotic family *Caponiidæ*, the chief peculiarity of which is the transformation of the front pair of lung-sacs into tubular tracheæ—a character in which this family is unique amongst spiders. The *Filitelariæ* contain the family *Filistatidæ* and genus *Filistata*; the latter being represented by several species, none of which are British. They are small or medium-sized



HOUSE SPIDERS.
a, Male; *b*, Female (nat. size); arrangement of eyes shown on left hand of figure.

species, easily recognised by the aggregation of the eight eyes upon a tubercle placed near the front border of the carapace, and of sedentary habits, spinning an extended web of white silk, in the form of an ill-defined tube.

To the *Tubitelariæ* are referred a number of families, presenting great variation both in structural features and instincts. The *Drassidæ*, for instance, spin no snare, but merely fabricate a silken case for themselves and young at the breeding-season, while others, like the *Agalenidæ*, which include the house spider (*Tegenaria atrica*), build a flat, sheet-like web, continuous at one extremity with a tubular retreat in which the spider lurks. The spiders of this last group which spin these sheet-like snares are furnished with three claws on each foot, and long posterior spinning mammillæ; whereas the *Drassidæ* and *Clubionidæ*, which live under stones, make no snare, and catch prey by chase or by lying in wait, have all the spinning mammillæ short, and only two claws on the feet. The above families differ from the preceding tribes of *Arachnomorphæ* in that the stigmata of the posterior pair of breathing-organs are not only united in the middle line to form a single aperture, but this has also, as a rule, moved to the end of the abdomen in front of the spinning mammillæ. In two of the families, however, these apertures,

although covered with a fold of the skin, are distinct from each other, and have only migrated part of the distance over the lower surface of the abdomen. These families, *Desidæ* and *Argyronetidæ*, have three-clawed feet like the *Agalenidæ*, but instead of being snare-spinners, fabricate a silken case to serve as a receptacle for their eggs and as a place of refuge. Both have an aquatic mode of life. The first family is represented by the genus *Desis*, found on the coasts and coral-reefs of the South African, Indo-Malayan, and Australian seas. At low water the reefs and rocks upon which they live are uncovered; but at the rising of the tide the spiders retreat into holes and crannies, where they surround themselves with a layer of silk strong enough to keep out water. They are good swimmers and feed upon small fish, crustaceans, etc. The *Argyronetidæ* live in fresh water, and are represented only by the water-spider (*Argyroneta aquatica*), frequenting ponds and ditches in the British Islands and other parts of Europe. Amongst the



WATER-SPIDERS, WITH NESTS (enlarged).

waterweeds the water-spider spins a thimble or bell-shaped web, the aperture of which opens downwards. Then, ascending to the surface and thrusting its abdomen out of the water, it succeeds, by some process not clearly understood, in enveloping the hinder part of its body in a film or bubble of air. Retaining this bubble in position by means of its hinder pair of legs, the spider swims down to its web, and inserting its abdomen into the aperture of the bell, sets free the bubble of air, which rises to the upper part of the cavity of the web and replaces a certain quantity of water. The spider then fetches down another bubble, and repeats the process until the web is filled with air; it then has a water-tight chamber, in which it can dwell till all the oxygen is consumed. Here the eggs are laid and hatched. This spider lives on insects which it catches in the water. Belonging to the family *Agalenidæ* is the genus *Agalena*, of which a British species (*A. labyrinthica*) is abundant in most districts, and spins a large sheet-like web upon hedges and bushes. At its inner extremity the web ends in a tube communicating at the back with the bush, into which the spider makes its escape when pursued. This spider is exceedingly agile, running with great speed

either on the ground or the upper side of its web. It has an ingenious method of overcoming insects like bees, with which it is afraid to come to close quarters, when they have fallen into the web. Attaching a thread to a spot close at hand, the spider runs in circles round and round its entangled prey, letting out the thread as it goes and gradually enveloping the insect, and effectually putting a stop to all struggles. Then, when it is tightly bound, the spider cautiously approaches, and, inflicting a bite upon the insect, puts an end to its life. Also belonging to this family is the so-called cardinal spider (*Tegenaria guyonii*), erroneously believed peculiar to the chapel at Hampton Court. Although none of the families of *Tubitelariæ* hitherto considered possess the cribellum and calamistrum, one family (*Amaurobiidæ*) is supplied with these organs. A well-known form is *Amaurobius similis*, which lives in holes in walls and ivy, where it spins an irregular, untidy, woolly web. The *Plagitelariæ* contain the family *Pholcidæ*, of which the genus *Pholcus* is the best known; one species (*P. phalangioides*) being not uncommon in the South of England, where in sheds and outhouses it spins a characteristic web, composed of a tangled mass of irregularly interlacing threads. This species has exceedingly long and slender legs, which at first sight give it a close resemblance to the harvest spiders. It moves slowly and clumsily; but when alarmed has a habit of hanging downwards in the web, by the tips of the toes, and swinging the body round and round with such rapidity that it becomes almost invisible. No nest is made, and the cocoon consists of a flimsy network, enveloping the eggs, which the mother carries about in her mandibles.

The next tribe—(*Retitelariæ*)—contains a host of spiders belonging to the families *Theridiidæ* and *Linyphiidæ*, most of which are of small size, while some are the smallest of all spiders. In structure they approach very near those *Tubitelariæ* which have no cribellum. The web consists of an irregular network of lines, or a horizontal sheet of silk, but there is no tubular retreat; and the spider crawls along the under instead of the upper surface of the web. The cocoon is suspended in or near the snare, and no nest is built for its reception. Of the first family a well-known representative is *Lathrodectus tredecimguttatus*, which somewhat exceeds the common garden grass-spider in size, and is either black or variegated with thirteen pale spots. Occurring in the countries bordering the Mediterranean, this spider spreads it webs over grass fields, and lives largely on grasshoppers. This species and others of the genus are much dreaded on account of their poisonous bite. The *Orbitelariæ*, or orb-spinners, containing the best known of all spiders, are closely allied to the *Retitelariæ*, from which they differ by the presence of a smooth spot upon the base of the mandible, and also by having a narrow space between the eyes and the base of the mandible. In this group the art of net-spinning has reached its highest point; all their claws on the feet being highly developed, while some of the hairs on the apex of the tarsi are barbed and toothed to form a kind of spurious claw. Such members of the tribe as possess a cribellum and calamistrum, belong to the family *Uloboridæ*, which contains the well-known European genera, *Uloborus* and *Hyptiotes*. Both these spiders are adepts at the art of concealment; the former spins a shabby orb-web in a hollow tree trunk and places of a like nature, and leaves in its web the débris of insects that have been

captured. It slings up, moreover, a string of cocoons, extending across the web, and at one extremity of the line, or amongst the dried carcases of flies, the spider takes its stand and harmonises so well in shape and colour with its surroundings as to be practically indistinguishable amongst them. Even more interesting is *Hyptiotes*, which frequents pine trees, and is a small thick-set little species almost invisible on the bark. It spins a web, triangular in outline, with anchoring threads passing from each of the angles to surrounding objects, and the triangular space filled in with cross-lines running parallel to the shortest side, and traversed in the middle by a single thread running from the apex to the base opposite. Taking up its position on the long anchoring thread which passes from the apical angle, and close to its point of attachment to the branch, the spider pulls in the thread so as to draw the whole net taut, coiling up the slack line between its front and hind-legs. The instant a fly strikes the net, the spider loosens its hold of the line, when the snare springs forward with a jerk, still further entangling the prey by bringing other threads into contact with it. If necessary, the net is snapped more than once, and when the spider feels that the insect is enveloped, it crawls leisurely along the web to devour it. The genus is common to Europe and North America. The other members of this tribe belonging to the family *Argiopidæ* have no cribellum nor calamistrum. Their webs vary in form, but are mostly of the orb type, consisting of straight threads radiating from a centre to the foundation lines, which are stretched from one point of support to another, and of a spiral line passing from the centre to the circumference, affording support to the radial lines and partly filling in the spaces between them. The spiral line is the principal part of the web involved in the capture of insects, many of its strands being covered with a series of gummy drops like beads on a string, which greatly hamper the movements of a captured insect. The presence and position of an insect in the web is perceived solely by the delicate sense of touch in the spider's feet, and for this reason the spider either takes up its stand in the centre of the web, where its eight legs can command all the radii, or else beneath some leaf at the end of a long thread passing from the centre to its place of concealment. In cases of danger the spiders either drop to the ground by a thread, or, seizing the web with the tips of their feet, start spinning the body round and round in circles and causing the web



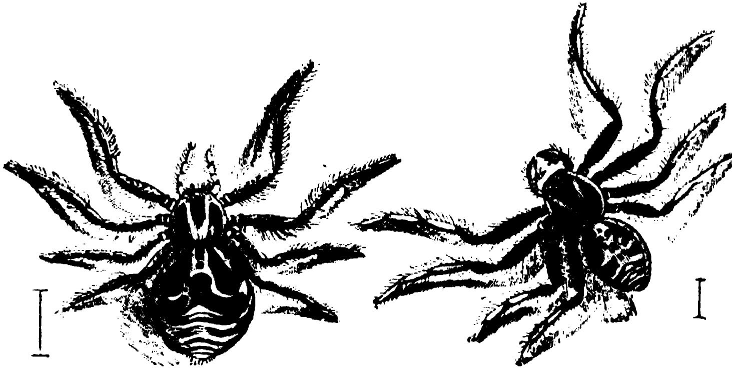
AN ORB-SPINNER (*Tetragnatha extensa*) AT REST IN ITS SNARE.

Arrangement of eyes shown above.



COMMON CROSS SPIDER, *Araneus diadema* (nat. size).

to oscillate rapidly until it and its occupant almost disappear from view. The commonest British members of the family belong to the genus *Araneus*, of which the cross or garden spider (*A. diadema*) is so abundant in gardens late in summer and autumn. Some of the tropical forms, such as *Nephila*, are of enormous size, and construct huge webs strong enough, it is said, to arrest the flight of small birds. The males are veritable pigmies, as compared with the females. Also belonging to the family are those curious tropical spiders of the genus *Gastracantha*, which are protected from enemies by having the integument of the abdomen hard, horny, and armed with spines. The figure on p. 231 of a species of *Tetragnatha* represents another tolerably common member of this family. It is characterised by its long and slender abdomen, and enormously strong projecting mandibles.

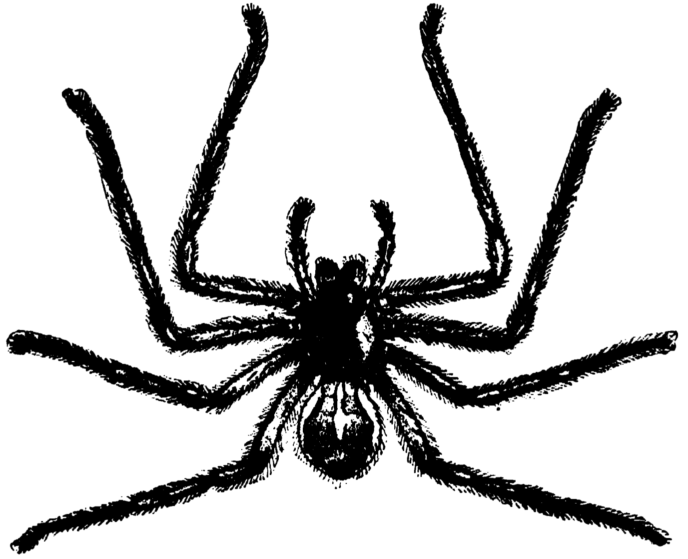


A SIDE-WALKING SPIDER (*Xysticus viaticus*). Female, left-hand figure; male right-hand figure (enlarged).

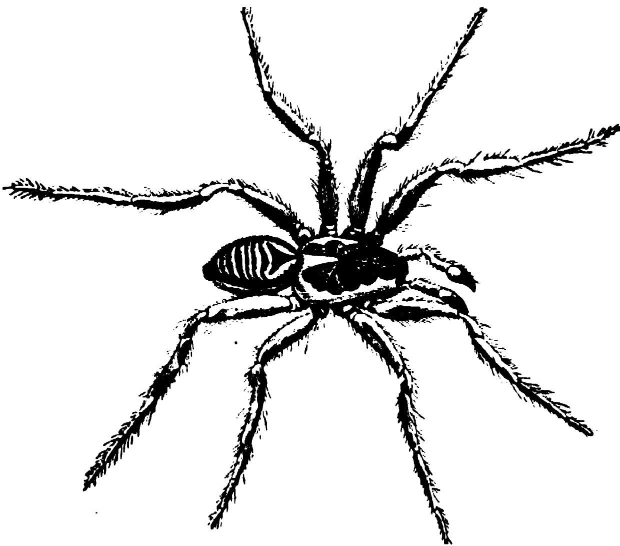
We now come to spiders differing from nearly all the preceding in that they obtain their prey by hunting instead of constructing snares. The first tribe of these, the *Laterigradæ*, derives its name from the fact that its members walk with a side, crab-like gait, a power which they owe to the rotation of their legs backwards in such a manner that the lower surface is turned forwards and the front upwards. The two first pairs of legs are longer and stronger than the others; the tarsi have but two claws, and the eyes are arranged in a double row. Of the families the so-called crab-spiders (*Thomisidæ*) include small squat-looking forms, with the two hinder pairs of legs weaker than the two front pairs. The carapace is broad and often biangulate in front, and the abdomen frequently wider behind than in front. These spiders are mostly sluggish and noticeable for their protective coloration. Those frequenting flowers for the purpose of seizing the insects that visit them possess the power of changing their tints to suit that of the blossom in which they take up their abode. The egg-cocoon is sometimes rolled in a leaf, sometimes left uncovered; but after constructing it the female forsakes her wandering life to watch over her offspring. The *Heteropodidæ* differ in having the mandibles more strongly toothed. The family is represented in Europe by a few spiders of medium size (*Sparassus, etc.*), but in the tropics by many of large size. One of the best known is the tropical house spider (*Heteropoda venatoria*), a large, long-legged species, introduced almost all over the hotter parts of the world. The female carries her lenticular cocoon tucked to the lower surface of the cephalothorax. The annexed figure of a South African spider (*Palystes*) shows the characteristic size and structure of the members of this family.

Passing over certain unimportant groups, we reach the running spiders, *Citigradæ*, which live on the ground, and capture prey by speed of foot.

The legs are strong, not very unequal in length, and armed with three claws; the carapace is high, with the head compressed, and bearing on each side two pairs of large eyes belonging to the hinder row, and in front the four smaller eyes of the first row in a straight or curved line. The typical members of the tribe belong to the family *Lycosidæ*, or wolf-spiders, of which a number of small forms are found in England, and the north and central parts of Europe. In summer these may be seen darting swiftly about amongst stones and grass, the female often carrying her cocoon attached to her spinning mammillæ. This cocoon is a spherical or more or less compressed sac, consisting of an upper and lower plate, fastened at the edges. The mother defends her packet of eggs with the utmost courage, and searches for it with diligence if lost. Soon after hatching, the young emerge from the cocoon, and climbing on to their mother's back cling there by means of silk threads, until strong enough to shift for themselves. The smaller species take refuge under stones or in crevices, and form no retreat; but many of the larger, especially those commonly known as Tarantula in South Europe, dig a burrow in the earth, lining it with silk, and in some cases building round the aperture a low circular wall of twigs or grass. To dig the burrow, the spider first loosens the earth with its mandibles, then gathering the pieces into a heap and sticking them together by means of silk and slimy matter secreted from the mouth, with a rapid flick jerks the pellet to some distance from the scene of its operations. At the entrance of the burrow the spider lurks on the look-out for passing insects, and during the



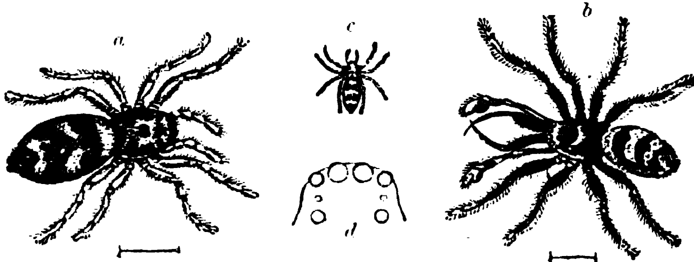
SOUTH AFRICAN SIDE-WALKING SPIDER, *Palystes* (nat. size).



ITALIAN TARANTULA SPIDER, *Lycosa tarantula* (nat. size).

winter covers up the aperture with silk and retires to the deeper parts to hibernate. In certain districts in the south of Europe these *Lycosidæ* are dreaded by the peasants, and fabulous accounts were given of the deleterious effects of their poison. The bite was said to be the cause of a disease of an epileptic nature called tarantism, and this could only be cured by music of certain kinds, which worked the sufferer up to a state of frenzy. Another family (*Pisauridæ*) differs in having the eyes of the front row separated by a wide space from the base of the mandibles. In this group *Pisaura mirabilis* is a common British spider, living in woods and fields, and at the breeding season constructing amongst grass or shrubs a large nest, open at the bottom. In this she lays her eggs, enveloping them in a thick cocoon which is carried about in her mandibles; but when the eggs are hatched, she retires to the nest and remains there with her young. The raft-spider (*Dolomedes fimbriatus*) is a large and handsome species, frequenting the borders of lakes and marshes, and owing its name to its habit of constructing a raft of leaves upon which it floats on the surface of the water. It can run with speed upon the water, and does not hesitate to plunge beneath the surface or run along the submerged stems of aquatic plants in chase of prey. The mother carries her cocoon in her mandibles; but at the time of hatching fastens it to some plant near the edge of the water.

The tribe *Saltigradæ*, or jumping spiders, contains the family *Attidæ*, all of which are of small or medium size, with a broad square head upon which the eyes are arranged somewhat as in the *Lycosidæ*; the anterior four being set in a straight line upon the front of the face, while the middle pair are of enormous size. The legs are stout, rather short, and, a rare thing in spiders, the third leg is often the longest; there are only two claws, the place of the lower claw being occupied by hair-tufts. For moulting, hibernation, and egg-laying, the jumping spiders spin a small saccular nest, which in the latter case is frequently open at one or both ends. In this the eggs are laid and hatched, and the young remain for some time under their mother's protection. Certain species depart from the normal type of structure of the others and closely resemble ants. This is brought about by the globular form of the abdomen, and a sharp constriction in the hinder half of the cephalothorax, so that the body appears to be divisible into three parts, as in an insect. Moreover, these spiders have learnt to walk with the gait of an ant, holding up a pair of its legs to simulate the antennæ. Thus disguised, they live in the company of ants, and avoid the persecution to which they would be subjected if their identity were not concealed. Why the ants refrain from destroying them is unknown. These spiders spin no snare, and are dependent upon agility and great keenness of vision for the capture of prey. Sighting an insect at a distance, and eagerly



JUMPING SPIDERS (*Epiblemum scenicum*). *a*, Female; *b*, Male; *c*, Female (nat. size); *d*, Arrangement of eyes.

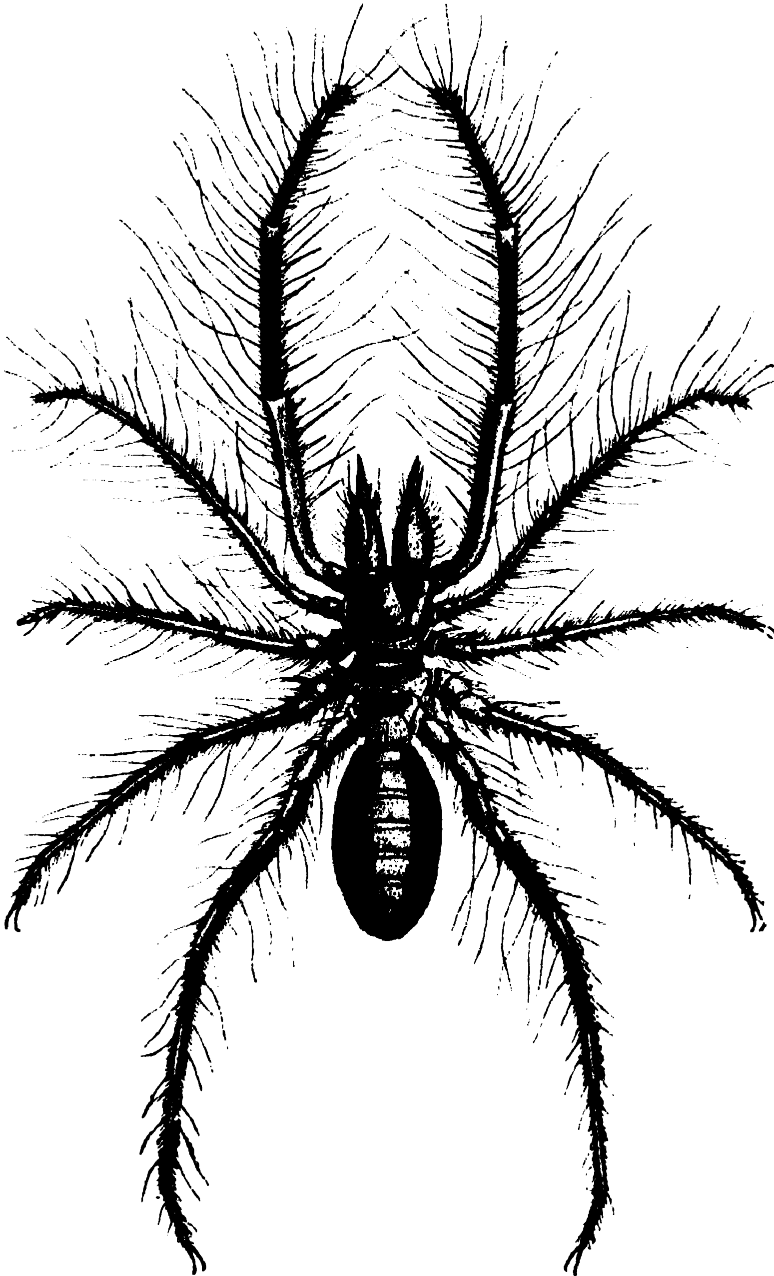
watching the while its every movement, the spider gradually stalks nearer, until within reach of a leap; then, with a well-judged spring, launches itself on to its prey, and, in spite of vehement struggles, tenaciously retains its hold until the victim succumbs to the paralysing effects of the poison. An Australian species (*Attus volans*) has acquired the power of prolonging its leaps into short flights, by elevating flaps of skin which arise from the abdomen.

THE FALSE SPIDERS,—Order SOLIFUGÆ.

The members of this group bear such a strong superficial resemblance to the true spiders that they are usually called by that name. The structural distinctions between the two orders are, however, so great and so easily ascertainable, that an example of the one may be without difficulty distinguished from an example of the other. In the first place, the abdomen is composed of ten distinct segments, and is not supplied with spinning-glands, while the breathing-organs, which are in the form of long tracheal tubes, open upon its second, third, and sometimes on its fourth sterna. The cephalothorax is distinctly jointed, its last two segments having separate tergal plates, while its front part is covered by a head-shield bearing a pair of large eyes near the middle of its front border, and merely traces of the lateral eyes at the sides. The mandibles, which form a powerful pair of toothed nippers, are articulated to the sides of the head-plate. The appendages of the second pair are palpiform and tipped with a sensory organ; but their basal segments, like those of the legs, are united together on the lower surface of the cephalothorax, which has no sternum. The three posterior pairs of legs are tipped with two claws each, but those of the first pair have only a single minute claw. On the basal segments of the last pair are certain racket-shaped organs, termed *malleoli*; and behind those of the second pair open a couple of large stigmata, leading into additional breathing-tubes. The mouth is situated at the tip of a long horny beak, projecting forwards between the mandibles. The males are smaller and lighter than the females, but have more powerful and longer legs and palpi. Their mandibles, however, are much weaker, and are furnished above with a sensory organ called the *flagellum*. In both sexes the mandibles are supplied on their inner adjacent surface with a set of ridges, which give rise to a grating sound when rubbed together. Both in Europe, Africa, and America, the *Solifugæ* closely follow the scorpions in their distribution, ranging in America from the Southern States of the Union southwards into Chili, and being found over the whole of Africa; none, however, have been recorded from Madagascar. In Europe they occur in Spain, Greece, and South Russia, being abundant and of large size in the steppes of the latter country. Thence they spread southwards and eastwards over the desert countries of South-Western Asia and India; but to the east of this point they become gradually scarcer, and although species have been discovered in Siam and the Moluccas, the group appears to be unrepresented in Australia and New Zealand. No extinct members have been described.

The order contains but a single family *Solpugidæ*, divisible into several well-marked genera, differing from each other in a number of structural characters. The largest members of the group belong to the genus *Solpuga*, confined to South

Africa, and to *Galeodes*, which occurs in great numbers in Persia, Arabia, Egypt, and South Russia. Another well-known form is *Rhax*, having the same range as *Galeodes*, but being a smaller and shorter-legged type. In habits the false spiders



MALE OF PERSIAN FALSE SPIDER, *Galeodes* (nat. size).

are both diurnal and nocturnal; specimens of *Galeodes* and *Rhax* roam about deserts at night, and, attracted by the light, make their way into the tents of travellers, while at other times they may be met with darting about in the blazing

mid-day sun. Most species of *Solpugidæ* are extremely active, running with great speed; but those of *Rhax*—which have enormous mandibles and short thick legs—are slow movers, and it is probable that the equally short-legged South African *Hexisopus* is also relatively sluggish. When on the prowl, these creatures carry the body raised high on the posterior six legs, those of the first pair and the palpi being lifted up and waved in the air to feel the way, while the movements of the head from side to side bear witness to their eagerness to discover prey. Many stories are told of the courage and voracity of these animals. Their food seems to consist mostly of beetles or other insects; but they will not hesitate to attack such redoubtable adversaries as scorpions.

The False Scorpions,—Order Pseudoscorpiones.

The false scorpions are all of minute size, the largest not exceeding a quarter of an inch in length. They owe their name to the fact that, as in the true scorpions, the appendages of the second pair are of enormous size as compared with the body, and form pincers; the mandibles being small, and also pincer-like, while all the legs are of the ordinary locomotor type. There is, moreover, no waist separating the thorax from the abdomen, and the latter is distinctly jointed. All these characters impart a considerable superficial likeness to scorpions, and formerly the two groups were looked upon as closely allied, although there are in reality many important, deep-seated differences between them. The abdomen, for instance, in the Pseudoscorpiones, is practically the same width throughout, none of the posterior segments being narrowed to form a tail, and the last bears no skeletal piece at all comparable to the scorpion's sting. The breathing-organs in the false scorpions are structurally of the same nature as those of the *Solifugæ*, consisting of tracheal tubes, which open by two pairs of stigmata, situated upon the third and fourth abdominal segments. Like the true spiders, the false scorpions possess silk-glands, but these are situated, not in the abdomen, but in the cephalothorax, and open by minute apertures at the tip of the movable fingers of the mandibles. In addition to these glands, there are others in the abdomen termed cement-glands, which open upon the second and third sternal plates. The function of these is not known, but it has been suggested that they may secrete the gummy material which causes the eggs to adhere together. The eyes, either two or four in number, are placed on the sides of the forepart of the head-region.



BOOK SCORPION, *Chelifer cancroides* (much enlarged).

The false scorpions, which occur in all temperate and tropical countries, live for the most part under stones and the bark of trees, or hidden in moss or vegetable rubbish; only two European species, namely, *Chelifer cancroides* and *Chiridium museorum*, are commonly found in human dwellings, in dark corners and the wainscoting of rooms, in herbaria, or even in boxes of insect collections. Under these conditions the former is but rarely met with, but large numbers have been taken together in old bee-hives, wasp-nests, and badly kept pigeon-houses. The two species, however, are by no means found exclusively in habitats of this nature,

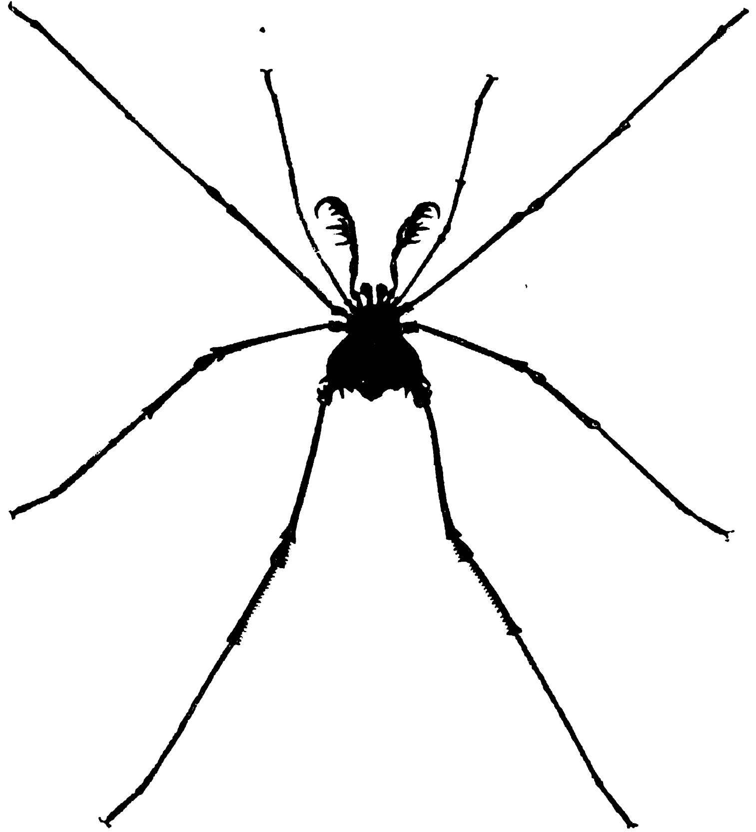
both having been observed under the bark of trees, far from the abodes of men. In South America it is by no means uncommon to find species of *Chelifer* living beneath the elytra of the large longicorn beetles. Some species frequent caves and grottoes, and many of these, from dwelling permanently in the dark, have lost all trace of eyes. Lastly, there are others which occur exclusively upon the seashore. *Garypus littoralis*, for instance—the giant of the order, so far as Europe is concerned—being found in Spain and Corsica at the foot of the cliffs and beneath seaweed, while, on the south coast of England *Obisium maritimum* may be met with under the same conditions. The *Cheliferidæ* are, for the most part, slow in their movements, walking with the pincers extended to feel the way, although they also progress with facility sideways or backwards. The *Obisiidæ*, on the contrary, are much more agile, darting backwards with great speed when alarmed. Some species of the genus *Chithonius*, indeed, are said to possess leaping powers of no mean order.

Although possessing silk-glands, the false scorpions have not learnt the art of ensnaring prey after the manner of spiders. They merely use the silk for constructing a small oval or spherical protective cell at the time of egg-laying, or for purposes of hibernation, or moulting. A species of *Chelifer* has been observed to build a cell, in the first instance, when preparing to moult, and in this receptacle it stayed for five days, until the new integument had acquired its normal strength. But about three months afterwards it returned to the same quarters to spend the winter. As a rule these cells, or cocoons, are left uncovered, attached to the under sides of stones, etc., but the Alpine *Obisium jugorum* covers its case with pieces of earth and of vegetable débris. Like the majority of the class, false scorpions are oviparous; the number of eggs rarely exceeding fifty, although these are of relatively large size. By means of a gummy material, the eggs stick together into a rounded or oval mass, which remains adhering to the ventral surface of the abdomen of the female. The young stay with their parent until they have acquired their definite form, but, when first hatched, show no signs of segmentation, either of the body or limbs, and the abdomen, which is folded against the lower surface of the cephalothorax, bears rudiments of four pairs of appendages, which subsequently disappear. The only fossil remains of the group hitherto discovered occur in the Tertiary amber beds of the Baltic; the species being apparently generically identical with those existing at the present time.

THE HARVEST SPIDERS,—Order OPILIONES.

Although the members of this group are frequently confounded with the true spiders, yet, as in the case of the scorpions and false scorpions, the resemblances between the harvest spiders and the true spiders are comparatively few and superficial, while the distinctive characters are many and deep-seated. In the first place, the body is oval, and the abdomen, which is united throughout its length with the cephalothorax, is, as in the scorpions and false scorpions, composed of from three to eight segments. The carapace which is short, unjointed, and usually bears one pair of eyes, is sometimes fused with the anterior segments of the abdomen; while in some cases the dorsal plates of all the abdominal segments are united to

one another and to the carapace to form a single large plate, its separate elements being merely defined by shallow grooves. The lower surface of the carapace is either almost wholly covered by a forward prolongation of the sterna of the anterior abdominal segments, or by the ingrowth of the coxæ of the appendages. The mandibles are composed of three segments, and are always pincer-like, and sometimes very powerfully developed. The appendages of the second pair (maxilla and palpus) consist of six segments, and are never chelate, although in some species they are armed with spines, and the claw is much enlarged and capable of being folded back upon the tarsus. In these species the appendage is used as an organ of attack and defence. The four pairs of legs are alike in form and function, being used for locomotion. In addition to the mandibles and maxillæ, there are often accessory mouth-parts, taking the form of masticating lobes on the maxillæ and the coxæ of the first and second pairs of legs; while above the mouth there is frequently a labrum, or upper lip, and above this a second piece, or clypeus. As in false scorpions, breathing is effected by means of tracheal tubes, opening by a pair of orifices situated on the sternal plate of the abdomen, immediately behind the coxæ of the first pair of legs. In addition to these stigmata, there is one on each side of the cephalothorax lying below the edge of the carapace and above the coxæ of the first pair of legs. These were originally regarded as the apertures of breathing-organs, but it is now known that they lead into glands, probably secreting an odorous and repellent fluid. In some species of harvest spiders, the males and females are almost exactly alike; but usually the two sexes are recognisable by sharply marked characters. In the males, for instance, the body is smaller and often more brightly coloured, while the legs are both longer and more strongly spined, some of their segments being often modified in shape. The greatest modification, however, is found in the mandibles,

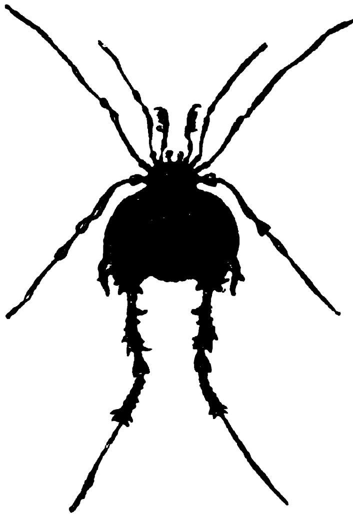


SOUTH AMERICAN HARVEST SPIDER, *Gonyleptes spinipes* (nat. size).

which are often much enlarged; in the male of *Phalangium opilio,* for example, the second segment is produced upwards into a great horn-like process. Fossil forms occur in the Carboniferous, one of which has been described as *Eophrynus.*

Suborder **Laniatores.**

In the harvest spiders of this group the first sternal plates of the abdomen do not project forwards to any great distance between the coxæ of the cephalothoracic limbs; the first being thus separated from the mouth by a long though narrow sternal area lying longitudinally between the coxæ of the right and left sides. The claw of the palpi is usually long, strong, and folded backwards against the tarsus, while the other segments are generally furnished with strong spines. Only the last four segments of the abdomen are free, the anterior coalescing with the carapace, which bears a pair of eyes, situated usually upon a single dorsal tubercle. This suborder is represented by numerous families in the tropical countries of both Eastern and Western Hemispheres. South of the Equator it extends to a considerable distance, reaching in South America as far as Tierra del Fuego; although in temperate lands to the north of the Equator it is poorly represented, there being only a few species of small size in Europe and the United States. In the tropical parts of Central and South America the group attains its maximum of development, both as regards species and genera, and the abundance and size of individuals. In the families *Cosmetidæ* and *Gonyleptidæ*, for instance, specimens sometimes reach an inch in length, and cover with their long slender legs a span of many inches. The suborder also has representatives in South Africa and Tropical Asia.



CHILIAN HARVEST SPIDER, *Gonyleptes chilensis* (nat. size).

An aberrant group of the Laniatores is the family *Sironidæ* containing a few species from South Europe and the Oriental countries. These are all of small size with elongate oval bodies, and relatively short and stout legs. The palpi, moreover, are not armed with spines, thus resembling those of the following suborder; and the legs are tipped with a single claw. The two eyes, which are situated at the sides of the carapace, are raised on stalks, and generally there is an additional eye on each side at the base of the stalk.

Suborder **Palpatores.**

These harvest-spiders differ from the preceding group in having the anterior sternal areas of the abdomen thrust far forwards between the bases of the thoracic limbs, so as to lie just behind the mouth. The claw of the palpi is short and weak, and these appendages are small and unspined, being used merely as organs of touch and not of prehension. The legs, moreover, are furnished with a

single claw. This group has a more extensive range than the last, being represented by a number of forms in Central and South Europe, and extending even to the Arctic Circle. The best known family is the *Phalangiidæ*, which is exceedingly rich in genera and species, and appears to be almost cosmopolitan in distribution. The body is often soft-skinned, small, and sometimes almost of the size and shape of a pea, while the legs, on the contrary, are exceedingly long and slender, and even thread-like. Still more curious are the members of the family *Trogulidæ*, in which the integument is hard and thick, while the legs are short and stout, and the front part of the head is produced forwards on each side into a distinct plate, meeting its fellow of the opposite side to form a hood, hollowed out below, and concealing the jaws and mouth-parts.

Group Ricinulei.

Tacked on to the Opiliones is a small group termed Ricinulei, which differs in many important characters from the harvest-spiders. The mandibles, for instance, consist of only two segments, and the palpi of only four (five with the maxilla). Moreover, the anterior part of the carapace is furnished with a movable hood, or *cucullus*, completely concealing the mouth; and the abdomen consists of only five segments. The legs are short, stout, and have two minute claws.

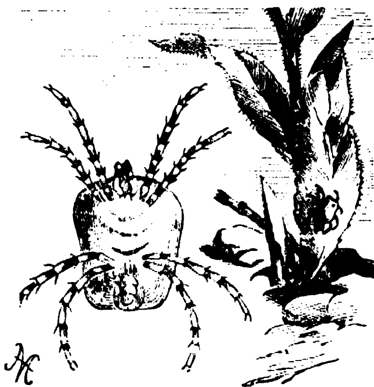
Considering the differences in structure presented by the various groups of Opiliones, it is not surprising that corresponding differences occur with respect to habits. The species with short, stout legs, and relatively heavy bodies, like *Trogulus* and *Stylocellus*, are very sluggish, *Trogulus* lifting its legs one at a time, and with apparent effort, and at the slightest danger ceasing all movement. This immobility, coupled with the protective covering of earth that adheres to its integument, conduces to the creature's safety by enabling it to escape observation. The Palpatores and Laniatores, with their long slender legs and light bodies, are much more active, and run off with speed when alarmed. Apart from the agility which it confers, the extreme length of limb possessed by these *Phalangiidæ* stands them in good stead by enabling them to stand on tiptoe and out of reach when threatened with destruction from armies of ants, which in tropical countries kill and devour every creature small enough to be overcome by numbers.

The Mites and Ticks,—Order Acari.

The mites and ticks constitute a group which, for diversity of structure, number of species and individuals, and minuteness of size, has no equal in the class. Many are wholly parasitic in habit, and have become so profoundly modified in organisation, and their affinities with the rest of the Arachnida so masked by degeneration, that some authors have proposed to remove the Acari into a class by themselves. Nevertheless, most of the species which lead a free life and have departed least from the type of structure characteristic of the Arachnida, show so many points of resemblance to the Opiliones, that it is by no means easy to draw a hard-and-fast line between them. One leading character, however, by which the ticks may be distinguished from the Opiliones is that the abdomen never presents

any trace of segmentation; it is confluent with the cephalothorax, the fusion between the two being so complete, that, as in the harvest-spiders of the group Palpatores, the anterior sternal plates of the abdomen are thrust far forward between the coxæ of the cephalothoracic limbs. As in all Arachnida, the mouth is adapted for sucking, but the jaws are often partially united, and form, with a plate termed the *epistome*, and the *labium*, a beak. The epistome is often of large size, and is attached to the front border of the carapace; the mandibles are either pincer-like or simply pointed at the tip, forming piercing organs. The palpi, which resemble a pair of small legs, have their basal segments, or maxillæ, united together and to the labium, to form a conspicuous plate or *hypostome*, constituting the floor of the mouth. These organs forming the mouth-parts are often separated from the rest of the cephalothorax by a membranous joint, and constitute a kind of movable head, the *capitulum*. In many cases there are no traces of special respiratory organs, breathing being effected by means of the skin; but, when present, such organs take the form of tracheal tubes, the apertures of which vary in position. They may, for instance, lie in the head between the mandibles and palpi, or far back in the body at the base of the legs of the last pair; but in some species they occupy intermediate positions, and open in front either of the first, second, or third legs. Another character of some value in separating the ticks from the harvest-spiders, is that in the former the young undergo a metamorphosis in the course of growth, being hatched from the egg as six-footed larvæ, which later acquire the fourth pair of legs. The order may be divided into the typical mites and ticks (Acarina), and an aberrant worm-like group (Vermiformia).

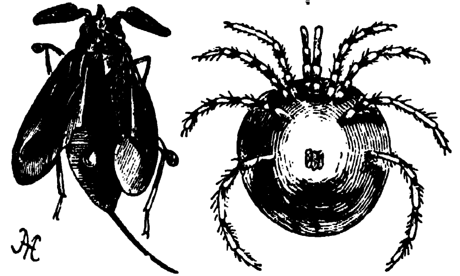
The Acarina include a number of families severally distinguished by the position of the respiratory stigmata, and the form of the mandibles and palpi. In the velvety mites (*Trombidiidæ*) the integument is soft and covered with variously coloured hairs; the legs are adapted for walking or running, the mandibles are pointed at the tip, and the stigmata open in the anterior portion of the body. There is usually a pair of eyes on the carapace, although these may be wanting. These mites, which may be either parasitic or leading a free life, feed by sucking the juices of animals or plants. A fairly common British species is *Trombidium holosericeum*, the second name referring to the clothing of crimson silky hairs covering its body. In the six-footed larval stage these mites live parasitically upon harvest-spiders, to which they cling, and resemble a cluster of bright red beads. Before attaining maturity they fall from their host to the ground, where, after undergoing their final moult, they lead a free wandering life, living upon minute insects such as aphides. In tropical countries mites of this genus reach a large size, measuring half an inch in length. They are beautiful and striking objects, resembling tufts of bright blood-red plush.



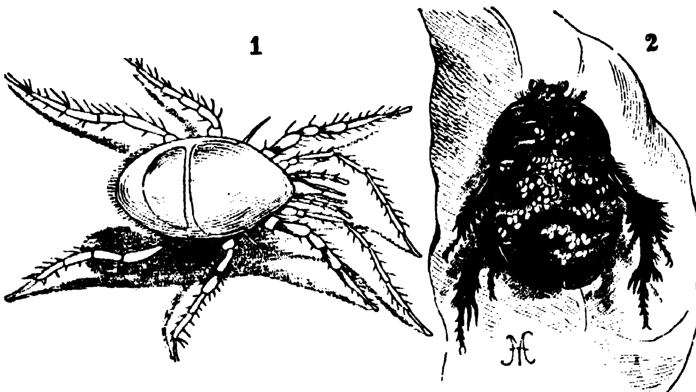
VELVETY MITE, *Trombidium holosericeum* FROM BELOW (enlarged eight times; nat. size on the leaf).

Nearly allied are the spinning-mites (*Tetranychidæ*), which live exclusively

upon plants, and obtain nourishment by sucking the sap. One of the best known is *Tetranychus telarius*, a little red mite, sometimes called the money-spider. The web it spins is of very fine texture, and may usually be found on the backs of leaves, where it appears to be merely used as a protective screen for both adults and young. The silk is secreted from a conical nipple situated on the under side of the extremity of the abdomen, and, as in the case of spiders, is manipulated by the appendages. Also related to the *Trombidiidæ*, but connecting them with the next family, is the common mud-mite, *Limnochares*, which lives in fresh-water ponds, creeping upon the mud or the leaves of aquatic plants. The larva adheres to various water-insects. The water-mites (*Hydrachnidæ*) have been described as *Trombidiidæ* that have adopted an exclusively aquatic life. They live in fresh-water ponds and streams, where they may be seen swimming freely by means of vigorous strokes of their legs, which act like oars. In the adult the body is generally more or less spherical, and usually of a bright red or green colour. The males of one species (*Atax globator*) have a curious blunt tail-like prolongation from the hinder end of the abdomen. The eggs are laid in the spring, in the stems of water-plants which are perforated for the purpose, and the six-footed larvæ when hatched attach themselves to water-bugs (*Nepa*), or water-beetles (*Dytiscus*), by means of a large sucker on the front of the head. The abdomen then starts growing, the feet drop off, and the creature remains hanging like a sack to its host. One species (*Atax bonzi*) lives in the shell of the fresh-water mussel, while a few (*Pontarachna*) are marine. The next family (*Halacaridæ*) contains marine forms differing from the last in many important features; the mouth-parts being more united. In addition to the pair of eyes on the carapace, there is an unpaired eye upon the epistome. These marine mites do not appear to swim like their fresh-water allies, but creep on the stems of sea-weeds and zoophytes. They may be obtained either by dredging in deep water or in rocky pools upon the coast. Passing on to the family *Gamasidæ*, we find the stigmata placed far back in the body, frequently at the sides of the thorax, above the legs of the third or fourth pair. The beak is imperfectly developed, the palpi being foot-like and free, and the mandibles pincer-like. There are no eyes;

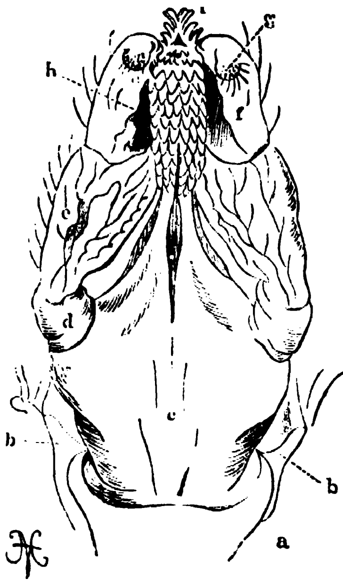


Right-hand figure, WATER-MITE (*Atax spinipes*), SEEN FROM BELOW; Left-hand figure. WATER-SCORPION, INFESTED WITH *Atax*.



1, BEETLE-MITE, *Gamasus coleoptratorum* (much enlarged); 2, DOR BEETLE, INFESTED WITH *Gamasus*.

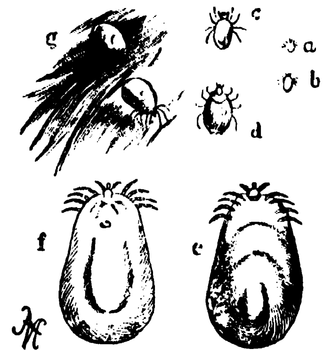
and the legs are adapted for walking or running. The species figured (*Gamasus coleoptratorum*) may often be seen in numbers attached to the lower side of dor-beetles. Others live parasitically upon bats and birds, one of the commonest being *Dermanyssus avium*, which infests poultry, canaries, and other cage-birds, whence they sometimes migrate to the persons who have charge of them. Ceylon, Sumatra, and Mauritius are the habitat of *Holothyrus*, in which the body is hard and horny, like that of a beetle, and of a shining chestnut colour.



MOUTH-ORGANS OF SHEEP-TICK.

c, Capitulum; *d*, *e*, *f*, *g*, Segments of palp; *i*, Spiny-beak, formed by fused mandibles.

Of all the Acari the best known and most troublesome are those belonging to the family *Ixodidæ*, which infest terrestrial vertebrates, and sometimes attach themselves to men. They are furnished with a longish cylindrical beak, armed with recurved hooks, and formed by the two mandibles above and the long slender labium below. The palpi are either free, as in *Argas*, or closely applied to the beak, forming in fact a sheath for it, and preventing the escape of blood, which flows from the puncture made by the beak. In the accompanying figure, showing the mouth-parts of the common English dog- or sheep-tick (*Ixodes ricinus*), the lower surface of the *capitulum*, or head-like process, which bears the beak is shown at *c*; *d*, *e*, *f*, *g*, represent the four segments of the palpi; *h* is the labial process armed with the hooks forming the lower side of the beak; and *i* indicates the tips of the two mandibles, forming its upper side, and projecting beyond the apex of the labium. By means of this beak, which is thrust to its base into the integument, the tick adheres firmly to its host, and in detaching them care must be taken that the head be not left behind buried in the skin. The species *I. ricinus* is commonly found in all stages of growth (see *a*, *b*, *c*, *d*, *e*, *f* of figure) adhering to cattle. The females pump themselves full of blood, and swell up to the size of a large pea; but the male—formerly regarded as a distinct species under the name *Reduvius*—is of smaller size, and resembles the empty female in shape. In distribution these pests are almost cosmopolitan, but in tropical countries they reach much greater dimensions than in temperate climes, the females sometimes attaining the size of a large gooseberry. In addition to mammals, they attack birds, tortoises, snakes, and lizards; and even the thick hide of the hippopotamus and rhinoceros is of no avail against attack. On account of their numbers, the effects they produce upon cattle are sometimes of a serious nature. These ticks are not, however, found



ENGLISH SHEEP-TICK.

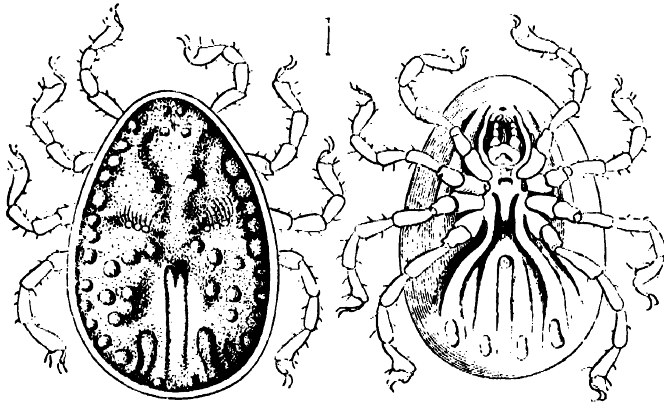
Six-legged young; *b*, Eight-legged young; *c*, Male; *d*, Female not distended; *e*, Female distended with blood from below; *f*, Same from above; *g*, Specimen clinging to the hairy integument of a mammal. (All figures enlarged twice.)

exclusively upon their hosts; they also occur on the ground, and under stones, where pairing and the hatching of the eggs take place. When in want of food, both old and young climb the stalks of grass and shrubs, and clasping the tips of the leaves with their fore-limbs, stand with the other legs stretched out behind, ready to catch the hairy skin of cattle as they sweep through the herbage. Also belonging to this family are the genus *Argas* and its allies, the species of which nearly equal the larger Ixodes in size, and although much less numerous in species and individuals have almost as extended a distribution. They may be at once distinguished from the latter by their coarsely granular skin, flattish bodies, and the entire concealment of the capitulum beneath the projecting fore-margin of the cephalothorax. The species here figured (*Argas reflexus*) is habitually parasitic on pigeons, and occasionally occurs in England in places where these birds abound. A closely allied form from Persia—where it is known as the poisonous bug of Miana—is much dreaded by the natives, its bite being said to produce convulsions, delirium, or even death.

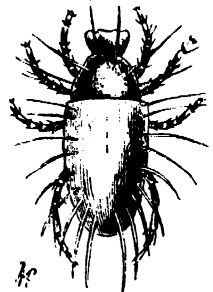


DOG- OR SHEEP-TICK (enlarged).

The next family (*Oribatidæ*)—the members of which are sometimes called beetle-mites, on account of their hard and horny integument—contains a number of species found for the most part under the bark of trees or in damp spots on the ground, where they live by sucking the juices of plants and minute animals. The palpi are free and tactile, the mandibles pincer-like, and the tracheæ, when present, open in the socket of the last pair of legs. The last family of true mites is that of the *Sarcoptidæ*, which are either free or parasitic. They have no special breathing-organs; the palpi are basally fused to the rostrum, the mandibles are pincer-like, and the tarsi are often furnished at their tips with a sucker. The most familiar of those that are not parasitic are the species known as cheese-mites (*Tyroglyphus*), which feed upon decaying organic matter. The common cheese-mite (*T. siro*), which has the body armed with rows of long stiff bristles, is also found in flour and linseed meal. Another allied species (*T. entomophagus*) frequently causes much havoc among insect-collections, entirely destroying the specimens if left unmolested, its presence in the cabinet being usually betrayed by the fine dust that results from its depredations. The most satisfactory method of destroying it seems to be soaking the cork of the box and the

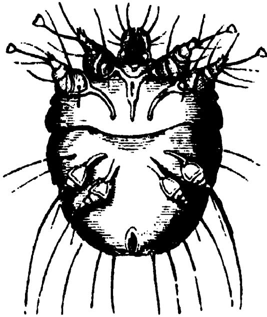


PIGEON-TICK, FROM ABOVE AND BELOW (much enlarged).



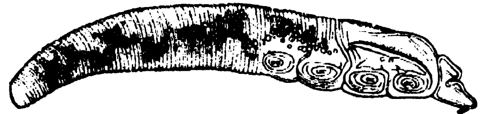
CHEESE-MITE (much enlarged).

specimens with benzine. A large number of mites living parasitically upon mammals—such as the mouse-mite (*Myocoptes*)—and birds also belong to the *Sarcoptidæ*; but the only species that we have space to mention is the itch-mite (*Sarcoptes scabiei*), which gives rise to the disease known as scabies. This malady and the irritation accompanying it are caused by the mite excavating tunnels under the skin. In these the eggs are laid, and hatch; and the young then start burrowing on their own account. The burrows usually show as whitish lines on the surface of the skin, and if the skin at the end of one of these lines be pricked with a sharp needle, the mite may be without difficulty extracted.



ITCH-MITE (enlarged 80 times). (Lower view of female.)

Worm-Like Group. In the group Vermiformia the elongate abdomen is divided into a multitude of small rings. There are no eyes and no tracheæ. The suborder contain only the two families *Demodicidæ* and *Phytoptidæ*. In the former the adult is provided with four pairs of short three-jointed legs; the mandibles are styliform, and the palpi formed of four segments, each armed with a claw. The family is represented by *Demodex folliculorum*, a minute mite less than $\frac{1}{50}$ of an inch in length, living parasitically in the sebaceous sacs and hair-follicles of the human skin. The same or an allied species has been found in the skin of a dog suffering from mange, where they occurred in such quantities that thirty or forty might be seen in a single drop of matter. The members of the second family, commonly known as gall-mites, have lost all trace of the third and fourth pairs of legs; the first and second pairs only remaining and projecting from the forepart of the body. These legs are long and five-jointed, the mandibles are styliform, and the palpi tactile and united at the base. The long body is furnished with symmetrically arranged bristles. There are numbers of species, living exclusively upon the leaves of plants, to which they do much damage by the excrescences or galls they form. Each kind of tree seems to be infested by its own special gall-mite, the so-called nail-galls of the lime being caused by a species named *Phytoptus tiliæ*. These galls take the form of more or less cylindrical pointed columns, which stand erect on the upper side of the leaves. As a matter of fact, they seem to arise as an inpushing of the lower surface of the leaf to form a long pouch or pocket, in which the mites live. Galls of much the same structure, although differing somewhat in shape, occur in the sycamore, maple, elm, and various fruit-trees. Other species, like the *Phytoptus* of the currant and the yew, attack the young buds and prevent them attaining maturity.

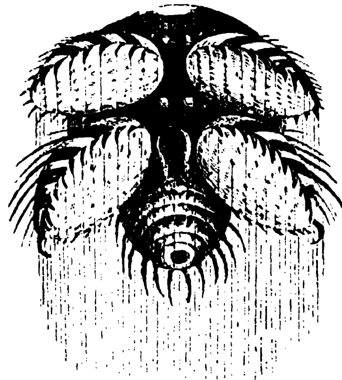


Demodex folliculorum (enlarged 600 times).

Aberrant Types. The mites and ticks complete the list of Arachnida; there remain, however, two small and obscure groups, which have been associated with the ticks, but apparently for no better reason than that their affinities are unknown. The first of these are the Tardigrada, or bear-animalcules, which comprise microscopical animals living in damp sandy and mossy spots. The body is long

and oval in shape, and possesses four pairs of bud-like unjointed appendages, each tipped with two claws. The last pair of legs projects from the extreme hinder end of the body. The mouth is situated at the opposite extremity, but the only trace of jaws that it presents is a pair of stylets. There appear to be no organs of respiration or circulation; and, unlike what obtains in all true Arachnida, the sexes are united in each individual. The second group, Linguatulina or Pentastomida, is still less like the Arachnida. It includes internal parasites, which in form and mode of life present many points of resemblance to the intestinal worms. The body is long, broad in front, narrowed behind, and divided into a vast number of rings. Near the mouth there are two pairs of strong hooks, and although these are the only traces of appendages that the adult presents, the embryo is furnished in addition with two pairs of limbs, tipped with claws. It is mainly upon the evidence furnished by these limbs that the Linguatulina are regarded as degraded mites. One of the best known forms is *Pentastomum tænioides*, which in the adult stage lives in the nasal passages of dogs and wolves. From these hosts the embryos escape to the outer world mixed up with the nasal mucus. Taken into the body along with the food of the hare or rabbit, they emerge from the egg, penetrate the walls of the intestine, and lodge themselves in the liver. Here they become encysted, grow, and go through a series of changes of form, accompanied by repeated ecdyses, until they pass into a state known as *Pentastomum denticulatum*. If the flesh of the rodent containing *P. denticulatum* be devoured by a dog, the parasite passes into the skull of the dog, gradually takes on the form of *P. tænioides*, and acquires sexual organs. Another species has been found living in the lungs of the Egyptian cobra, and a third in those of a species of boa.

R. I. POCOCK.



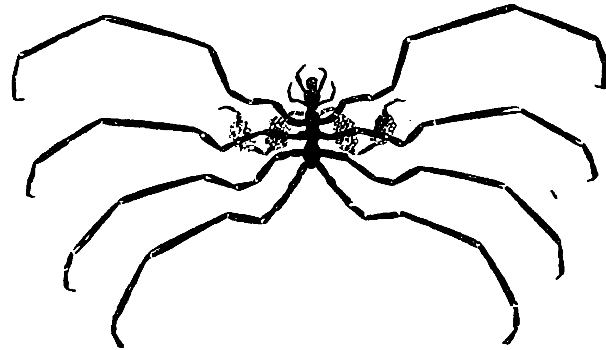
A SPIDER'S SPINNERETS (greatly magnified).

CHAPTER VII.

THE JOINTED ANIMALS,—*concluded.*

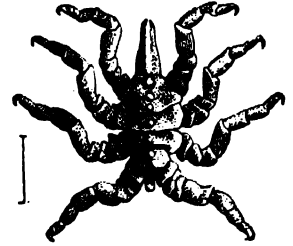
THE SEA-SPIDERS, KING-CRABS, AND CRUSTACEANS,— Classes **Pantopoda, Gigantostraca,** and **Crustacea.**

THE animals belonging to the first of the three classes named above present such a marked general resemblance to the true spiders, that they have been included in the same class. On the other hand, from their marine mode of life, some writers have come to the conclusion that their affinities are rather with the Crustaceans. As a matter of fact, it appears impossible to affiliate them with either of these groups, and the general opinion is that they are entitled to form a class by themselves. In all these creatures the adult is provided with four pairs of well-developed legs, composed of a large and varying number of segments, and each tipped with a single claw. These limbs, which are often exceedingly long and slender, radiate from the sides of the cephalothorax, which is produced into stalks for their support. In front of these limbs, and attached to the headpiece, are sometimes three additional pairs of appendages. Hence the full complement of limbs is seven, and not six pairs as in the true spiders. The first pair of appendages, forming the mandibles, are short and often pincer-like; the second pair, or palpi, being also short; while the third pair, which are only developed in the females, are shorter than the true legs, and, from their function, are termed the egg-bearing legs. In some cases, however, these three pairs of appendages have entirely disappeared, as in the shore-spider (*Pycnogonum littorale*). Projecting forwards from the front end of the body is a long rigid beak, or proboscis, at the tip of which the mouth is situated. This beak is not formed by the fusion of limbs, like that of the ticks, but results from the great development of the area immediately around the mouth. The cephalothorax is divided into four distinct segments, of which the first, or head, supports the first four pairs of appendages, and has on its summit a pair of eyes, while the rest bear the three posterior pairs of limbs. Attached to the last of these segments, and projecting



FEMALE OF SLENDER SEA-SPIDER, WITH EGGS (much enlarged).

backwards between the last pair of legs, is the abdomen, which is reduced to a mere tubercle or rod-like process. The greater part of the body-cavity is occupied by the stomach, which sends prolongations almost down to the extremities of the four pairs of walking-legs. No breathing-organs are known.



SHORE-SPIDER (enlarged).

The sea-spiders are exclusively marine, and range from shallow water to depths of sixteen hundred fathoms or more. The conditions of life in the deep sea have by no means a dwarfing effect upon them, since the species living in the abysses of the ocean attain a size never equalled by those frequenting the coast. Some of the former are of a very large size; *Colossendeis gigas*, for instance, covering a span of nearly two feet from toe to toe. None are able to swim, but all crawl slowly amongst the branches of seaweed. The embryo emerges from the egg as a larva, provided with a beak and three pairs of appendages, representing the short anterior three pairs of the adult; the four pairs of great locomotor limbs being subsequently produced by outgrowths from a posterior elongation of the body.

THE KING-CRABS,—Class **Gigantostraca.**

In many respects the representatives of this class occupy a position intermediate between the Scorpions and Spiders and the Crustaceans. From the fact that they are marine and breathe by means of gills, they were formerly always classified with the Crustaceans; but a large amount of evidence has been brought forward to show that whereas the earliest kinds are related to the primitive Crustaceans, the more specialised kinds are strikingly like some of the Scorpions. The class contains three orders, named Xiphosura, Merostomata, and Trilobita. The last two of these are now entirely extinct, and the first named nearly so, since it is represented at the present day by only a single genus, the king-crabs or horse-shoe crabs (*Limulus*). In the existing group, forming the order Xiphosura, the body is armed behind with a long spike-like tail, movably articulated to the middle of the hinder border of the abdomen. The abdomen consists of a large unsegmented pentagonal plate, armed on each side with six movable spines, and hollowed out below to receive six pairs of large flattened limbs, attached to the anterior part of its lower surface. With the exception of the first, each limb supports on its hinder surface a bunch of fine branchial plates, arranged one above another like the leaves of a book. In front of the abdomen comes the cephalothorax, which is covered above with an enormous carapace, having its border semicircular and its hinder angles acutely produced. The carapace is furnished above with four eyes, two being small and simple ocelli, situated close together some little distance behind the front border, while the others are large kidney-shaped compound eyes, placed at a corresponding distance from the lateral margin. The great size of the carapace is due to the prolongation of its edges into a wide sloping shelf-like expansion, concealing the walking limbs. Of the six pairs of the latter, the first are placed in front of the mouth, and are short, three-jointed nippers; while the rest are longer, generally six-jointed, and all but the

Existing Forms.

last nipper-like, the last or sixth ending in a number of flattened plates. The basal segments of the second, third, fourth, and fifth limbs are furnished with large processes, projecting into the mouth and studded with numbers of slender softish spines. The mouth is thus situated between the bases of these limbs, near the middle of the lower surface of the cephalothorax. The males differ from the females in having the second, or second and third pairs of limbs thickened and otherwise modified. In the male of the round-tailed king-crab (*Limulus rotundicauda*) the second and third pairs are considerably swollen, and the two fingers of the nippers cross each other when closed; whereas in the Moluccan king-crab (*L. moluccanus*) the immovable fingers of these limbs are reduced to short processes.

In distribution, king-crabs are limited to the east coast of the United States, to the shores of China and Japan, and of the Indo-Pacific Islands, ranging from the



CHINESE KING-CRAB.

Moluccas to Singapore and Java. In the last-named area two species, *L. moluccanus* and *L. rotundicauda*, occur. The Chinese species is known as *L. longispinus*, on account of the long and strong spines projecting from the carapace and abdomen; while the North American species is *L. polyphemus*. The habits of the last-named species are tolerably well known. It spends the greater part of the year in water from two to six fathoms deep, and, being unable to swim, creeps about the bottom of the sea in search of food, or even lives buried in mud, into which it scoops its way. This it effects by thrusting the front edge of the carapace forwards and downwards into the mud, the tail behind being used as a prop, while the legs are engaged in raking up the mud and pushing it out sideways. The tail is also of service in helping the animal to regain its proper position if turned upside down. Digging the tip of the organ into the soil, the crab raises its body, and after a few efforts succeeds in struggling over. In fact, were it not for the possession of a long tail, the king-crab would be as helpless on its back as a tortoise in the same position.

King-crabs feed almost exclusively upon soft marine worms and bivalve molluscs. The food is seized and tucked into the mouth by means of the legs,

where the spines on the basal segments of these appendages crush and tear it to pieces. In May, June, and July, large numbers of king-crabs approach the coast in couples to spawn. Choosing spring-tides, they advance along the bottom until the water is shallow enough to allow the carapace to project above the surface. The female then scrapes a hollow in the mud, lays her eggs, and hurries back with her mate into deep water. By the action of the waves the eggs are soon covered with a layer of sand, and at ebb-tide are exposed to the warmth of the sun. When first it emerges from the egg, the young king-crab is a minute nearly spherical creature, with a fringe of stiff bristles running round the body, and differs from the parent in having no tail. Subsequently it undergoes a succession of moults, during which the form of the adult is gradually acquired, the tail appearing at the second change. The casting of the skin is effected by the splitting of the integument of the cephalothorax all round, immediately beneath the margin of the carapace. Through the aperture thus made the creature struggles forth, leaving its old shell behind. Before the growth of the tail the young king-crab is in a helpless state, the slightest obstacle turning it upside down. In this emergency it starts a vigorous flapping of its gill-plates, which cause it to rise in the water. Then ceasing the agitation, it at once descends with a chance of alighting right side up.

Extinct Types.

The existing king-crabs are the typical representatives of the family *Limulidæ*, and fossil remains of *Limulus* occur in the Tertiary rocks as wells as in the Cretaceous, Jurassic, and Triassic beds of the Secondary epoch. In the Palæozoic strata the class is represented by a number of forms, such as *Bellinurus* from the Carboniferous, *Protolimulus* from the Devonian, and *Hemiaspis* from the Silurian, which resemble *Limulus* in most of their characters, but differ in having the abdomen composed of at least nine distinct segments. On this account they are referred to a distinct family, *Hemiaspididæ*. It is, however, interesting to note that in the young king-crab the abdomen is also composed of nine segments, so that just as in the life-history of each individual king-crab the final and adult stage with a solid abdomen is preceded by a transitory stage in which the abdomen is jointed, in the history of the class the existing and final stage, represented by the adult king-crab of our own day, was preceded by a transitory stage, which, in the segmentation of the abdomen, was on a level with the young king-crab.

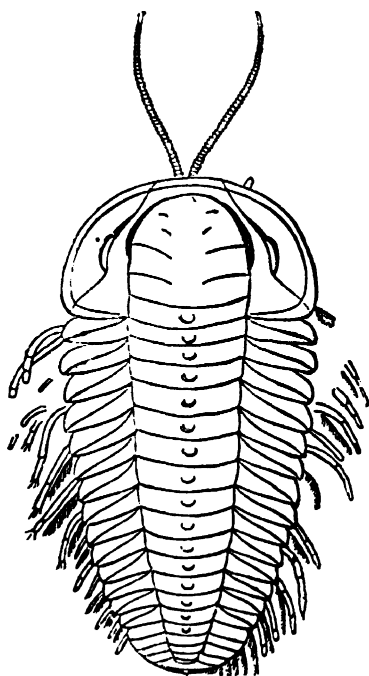
Merostomata.

The seas in which these fossil forms lived were also inhabited by some nearly allied types, differing from the king-crabs, both in habits and some important points of structure. The carapace, for instance, was much smaller and did not conceal the legs, the last pair of which were generally thickened and flattened, and transformed, as in *Eurypterus*, into powerful short paddles. In one form, however, named *Slimonia*, the legs of the last two pairs were enormously elongated, evidently to serve the purpose of oars. The abdomen was used as a propeller, and it was long and divided into twelve flexible segments, the last of which bore the tail-plate or telson. As in the king-crab, the bases of most of the cephalothoracic limbs were armed with teeth and acted as jaws; but those of the anterior pair formed either short tactile organs or long and powerful nippers, as in *Pterygotus*.

The Merostomata, as these animals are termed, appear to have lived both in

fresh and salt water, and their organisation seems to show that they were powerful swimmers; considering, too, the large size which some of the species attained, examples of *Pterygotus* reaching a length of from 4 to 6 feet, there is little doubt that these monstrous sea-scorpions were the masters of the ocean in Palæozoic times. A third order is represented by the extinct Trilobites or Trilobata, which swarmed in the seas of the Palæozoic epoch, and are amongst the earliest of known fossils. The name Trilobite, or three-lobed, is given to them because in the best known and typical members of the group the body is divisible into three distinct parts—an anterior cephalic shield corresponding to the head of the Crustacea and to the cephalothorax of *Limulus*, and formed, as in Crustaceans, of five fused segments; a median thoracic portion, composed of a variable number of freely movable segments; and the *pygidium*, also composed of a variable number of segments, but usually fused to form a great caudal shield. The lateral portions of the segments are produced sideways into great pleural plates, which mostly conceal the limbs, and the hinder angles of the cephalic shield are frequently prolonged into sharp spiniform processes, sometimes so long that they project backwards beyond the hinder end of the body. On the upper side of the cephalic shield there are a pair of large kidney-shaped compound eyes, but no sign of the simple eyes present in the Xiphosura and Merostomata has been discovered. For many years no trace of limbs could be detected, but it is now known that a pair of limbs was attached to the lower surface of each of the segments of the head and body; though instead of there being two pairs situated in front of the mouth, as in Crustaceans, there was only one, as in the Xiphosura, Merostomata, and Arachnida. These, however, take the form of long filiform antennæ, and are placed on each side of a large upper lip, or *labrum*, behind which comes the mouth. The rest of the appendages of the head, as well as those of the thorax, are alike, consisting of a large basal segment, from which spring two branches, an inner, which was used for crawling, and an outer, many-jointed and fringed with bristles, which was perhaps used for swimming. The basal segments of these limbs in the head region were utilised as jaws, and in the pygidium the inner branches, or *endopodites*, were flattened and more or less leaf-like as in the lower Crustaceans, such as *Apus*. There is little doubt that Trilobites, instead of swimming in the open sea and leading an active predatory life, spent their time crawling or swimming slowly along the bottom, feeding upon worms, burrowing in the mud, and, in case of danger, rolling up tightly into a ball like wood-lice. Many specimens are found fossilised in this condition, with the lower surface of the pygidium pressed against the head.

Trilobites.

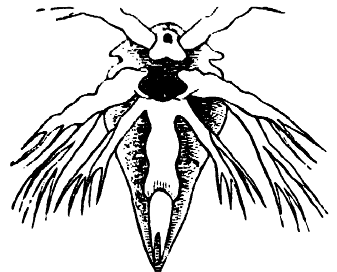


A TRILOBITE (*Triarthrus*).
(From Beecher.)

CRABS, LOBSTERS, CRAYFISH, etc.,—Class **Crustacea.**

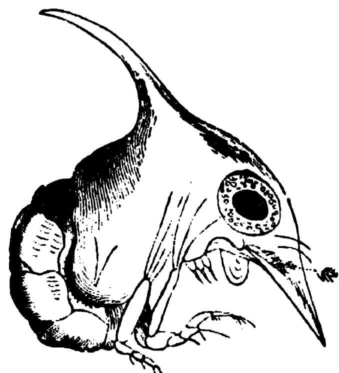
The Crustaceans comprise a large assemblage of Arthropods, presenting great diversity of structure. Some of the parasitic species have become so simplified in organisation that they appear to present no relationship with the higher members of the class, such as crabs, lobsters, wood-lice, etc. Yet it is certain that all the species, whether terrestrial or aquatic, free-living, sessile, or parasitic, belong to the same stock, and may be derived from the same fundamental plan of structure. Essentially the body consists of a large number of segments, to each of which is attached a pair of two-branched appendages, the external branch being called the exopodite and the internal the endopodite. Five segments at the front end of the body unite to form a head; the appendages of the first two of these segments being situated in front of the mouth, and performing the office of feelers or antennæ, while those of the remaining three segments are transformed into jaws, the first pair of jaws being the mandibles and the following two pairs the maxillæ. The rest of the appendages are variously modified, and to some are attached respiratory organs in the form of gills. According to this definition, Crustaceans may be distinguished from the Centipedes, Millipedes, Insects, etc., by the presence of two pairs instead of one pair of antennæ, and by possessing branchial and not tubular (tracheal) respiratory organs. The Arachnida may be separated from Crustaceans by having in front of the mouth only one pair of appendages, acting as jaws and not as antennæ, while respiration is effected by means of saccular or tubular ingrowths of the integument. Nor can there be any confusion between Crustaceans and the sea-spiders, since the latter have no antennæ and all their appendages are placed behind the mouth, which is situated at the extremity of a tubular proboscis. But when we come to the Gigantostraca it is not so simple to point out the differential characters of the Crustaceans. It is true that the king-crabs are easily distinguishable, and appear to be more nearly related to the Arachnida, yet the Trilobites, which seem to be ancestral forms of the king-crabs, show marked affinities to the primitive Crustaceans.

In a few Crustaceans, especially those leading a terrestrial life, or inhabiting fresh water, the young is very similar to the adult, and gradually attains maturity without going through any marked change of form; but in the majority the young upon leaving the egg is unlike the parent, and only acquires its definite form after undergoing a series of moults. The earliest stage, which has been called the *Nauplius*, is a minute oval body, showing no trace of segmentation, and provided with a single median eye, and three pairs of swimming appendages, which become the two pairs of antennæ and the mandibles of the adult. This stage, however, is by no means of invariable occurrence, but is chiefly characteristic of the lowest members—the Entomostraca—and is rare in the higher Malacostraca. In some members of the latter group, nevertheless, it does occur, as in one of the shrimps (*Penæus*). In this the Nauplius passes into a stage called the *Zoæa*, in which four pairs



NAUPLIUS LARVA OF BARNACLE (much enlarged).

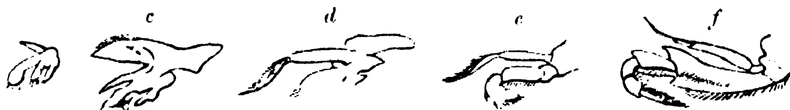
of appendages, representing the maxillæ and the two following pairs of limbs of the adult, have appeared, and the abdominal region has increased in length, although, like the greater part of the thorax, is still limbless. A pair of compound eyes is present on the sides of the head. After this so-called copepod stage, the large eyes become stalked, the abdomen continues to increase in length, and takes on the function of swimming, which was before performed by the antennæ, and the remainder of the thoracic and abdominal limbs appear. Since the thoracic limbs are provided with a distinct exopodite, as well as the principal branch or endopodite, as in the cleft-footed shrimps (Schizopoda), this larva is known as the schizopod stage. Lastly, the median eye and the exopodites of the motor-thoracic limbs disappear, and the adult form of the *Penæus* is attained. It is, however, exceptional amongst the higher forms for the young to be set free in the Nauplius stage. The young of the lobster, for instance, hatches in the schizopod condition; while that of the common crab appears in the Zoæa form, although characterised by the presence of a long dorsal spine, and a sharp beak on the carapace. Moreover, the two pairs of antennæ, the mandibles, and maxillæ, are of small size, while the following two pairs of limbs are relatively large, and forked. By means of these the minute transparent creature swims, and after undergoing several moults passes into a stage termed the *Megalopa*, which is much like the adult, but has enormously large eyes, and swims by flapping its long jointed abdomen like a shrimp.



ZOÆA STAGE OF CRAB (enlarged).

THE TYPICAL CRUSTACEANS,—Subclass **Malacostraca**.

Much difference of opinion still obtains as regards the classification of Crustaceans, which are here divided into two main subclasses. In the present group, comprising the largest and most familiar forms, the number of segments in the body is very generally nineteen (but never more), and each has a pair of appendages. The first five segments compose the head, which, except in some blind species, bears a pair of compound eyes, two pairs of antennæ, and three pairs of jaws, namely, a pair of mandibles in front, and two pairs of maxillæ behind. The eight segments behind the head, which constitute the thorax, may be united



JAWS OF CRAYFISH.
a, Mandible; *b*, *c*, Maxillæ; *d*, *e*, *f*, 1st, 2nd, and 3rd Maxillipedes.

with the head, as in crabs, when the whole region is termed the *cephalothorax*, and the shield that covers it the *carapace*. Sometimes too, as in the crayfish, the anterior three pairs of thoracic appendages are transformed into jaws, and on this

account are called the *maxillipedes*, or foot-jaws; and in such cases only the remaining five pairs, called the trunk limbs, are large, and used for locomotion or seizing prey. In less highly organised forms, all the maxillipedes may be free and foot-like, as in the mantis-shrimps, or only the anterior pair, as in sand-hoppers, may act as jaws. The remaining six segments, forming the abdomen, are usually provided with six pairs of small two-branched limbs, and to the last of these segments there is articulated a single plate, or telson, while the limbs, or uropods, are generally of large size, and form with the telson the tail-fin.

The Malacostraca are divisible into two series, the Podophthalmata, containing those in which the eyes are perched on movable stalks, and the Edriophthalmata containing those in which they are sessile, or if raised upon stalks not movable. The former are further distinguished by having the forepart of the body generally covered by a carapace; in the latter some of the thoracic segments are movable and there is generally no carapace.

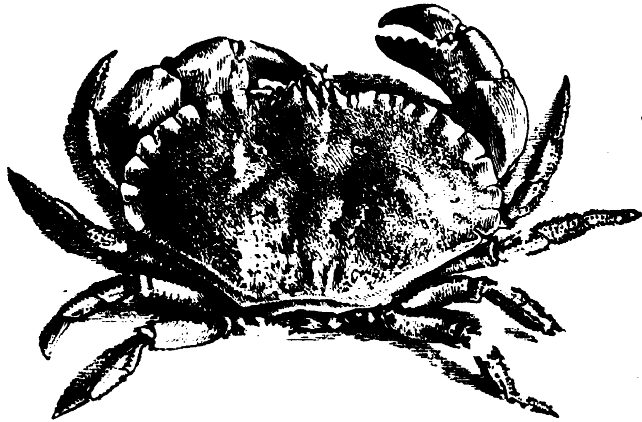
Decapods.

The first order (Decapoda) of the stalk-eyed series is characterised by having the posterior five pairs of thoracic limbs strongly developed, and forming either walking or swimming legs, or prehensile pincers. The three pairs of maxillipedes are generally transformed into jaws; but in some of the lowest forms, as shrimps, the third or last pair are long and limb-like, so that in reality there are six pairs of large thoracic limbs. The gills, which are attached to the sides of the cephalothorax and to the basal segments of its limbs, are concealed in a gill-chamber, formed by the lateral portions of the carapace. Each gill may be compared to a plume consisting of a central stem, to which is attached a number of delicate processes in the form of flattened plates or of filaments. The front aperture of the gill-chamber is closed by a movable plate called the *scaphognathite*, and attached to the second maxilla. During life this plate is in constant motion, baling out the impure water through the anterior opening, and thus compelling a flow of fresh fluid into the chamber through the openings at the hinder end of the carapace above the bases of the limbs.

Short-Tailed Group,—Suborder **Brachyura**.

Decapods are divisible into two suborders, the Brachyura, or short-tailed, and Macrura, or long-tailed group. The first-named suborder contains those members of the order which may be called crabs. Here the abdomen, or so-called tail, is small, and shorter than the cephalothorax, against the lower surface of which it is usually tucked away. In the males it is generally narrow, and bears only one or two pairs of appendages, but in the female it is broader and is furnished with four pairs of limbs. In neither sex is its last segment furnished with a pair of uropods forming the tail-fin. The lower surface of the cephalothorax is generally broad and triangular, and the third pair of maxillipedes are short and flattened, and form, when in contact, a plate completely covering the rest of the mouth-organs. The group is divisible into five tribes, the first of these being the Cyclometopa, or those with rounded foreheads. It includes most of the commoner species, such as the edible crab (*Cancer pagurus*), and shore-crab (*Carcinus mænas*). The former belongs to the family *Cancridæ*,

characterised by having the carapace much wider than long. As an article of food the male is more esteemed than the female, being larger and having larger claws. The two sexes, as in all crabs, may be distinguished by the size of the tails, this organ in the male being narrower, more pointed and having fewer and smaller appendages than in the female. The family *Cancridæ* is represented in tropical seas by a large number of species and genera, some of which, such as *Actæa*, have the carapace covered with granules, and ornamented with a network of deep grooves.

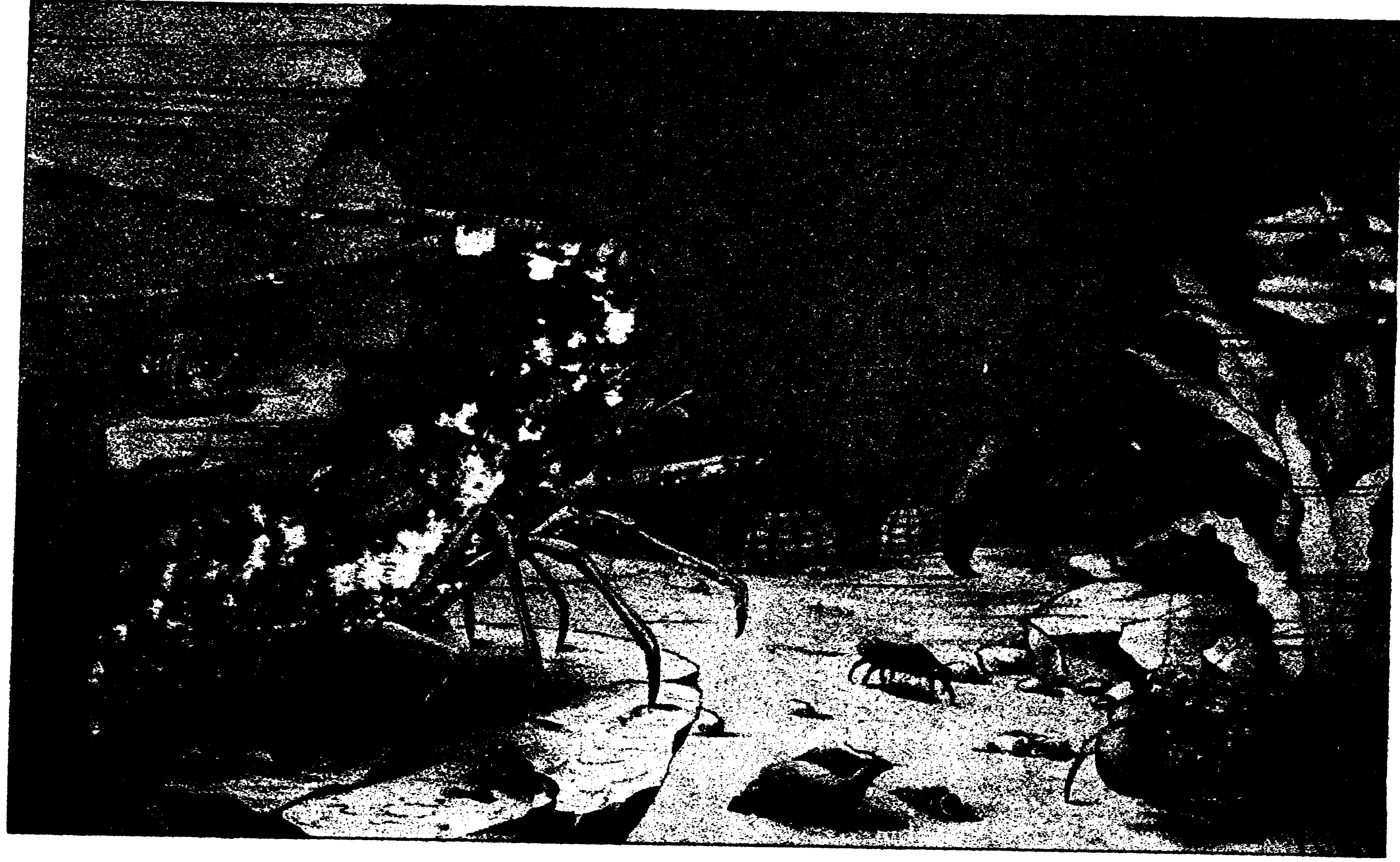


YOUNG EDIBLE CRAB.

The members of the family *Portunidæ* may be recognised by a modification of the last pair of legs. In the great majority of crabs these legs are like the rest, ending with a long, slender-pointed foot which bears evidence to its being an organ for running, climbing, or crawling; but in the *Portunidæ* these legs are much flattened, the last segment in particular being dilated into an oval plate. The creatures are thus equipped with a pair of oars, by means of which they swim. Several species of the typical genus *Portunus* are found in British waters, and many of them are handsomely coloured, although none are such expert swimmers as the tropical species, especially those inhabiting the gulf-weed of the Atlantic. The peculiar motion of the oar-like feet has given rise to the name of fiddler-crabs, so often applied to the group. The figured species (*Thalamita natator*) is a native of the tropical seas. The common British shore or green crab (*Carcinus mænas*), which is referred to this family, differs from the rest in having the legs of the last pair adapted for walking, being armed with a claw, and not flattened into a paddle. Connecting the present with the following section, is the family *Thelphusidæ*, which contains a number of genera and species found in fresh-water streams, or on land, and sometimes ascending mountains, in temperate and tropical regions. One of the best known species is



SWIMMING-CRAB (nat. size).

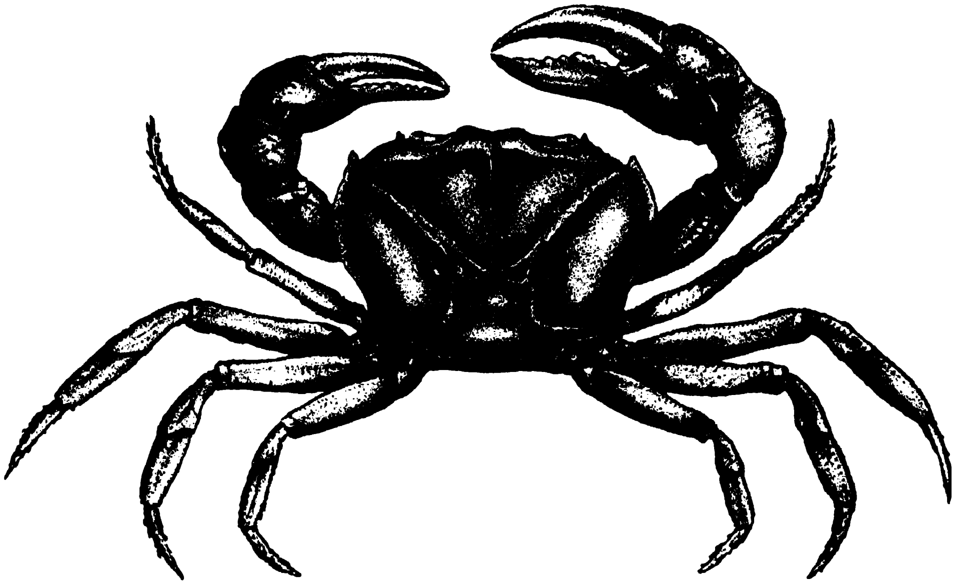


CRUSTACEANS

the South European *Thelphusa fluviatilis*, which swarms on the muddy banks of the Lake of Albano, and is also abundant in the neighbourhood of Rome, where it is captured for sale. Another well-known form is the Indian land-crab (*T. indica*), to which the species here figured is nearly allied.

The second tribe (Catometopa) is characterised by the broad and squared frontal region of the carapace being bent downwards. It is typically represented by the family *Gecarcinidæ*, including most of the true land-crabs. A large number of these belong to the genus *Gecarcinus*, which has representatives in both the Eastern and Western Hemispheres. Two inhabit the West Indian Islands, and of one of these (*G. ruricola*) from Jamaica a full account has been given by Mr. Browne.

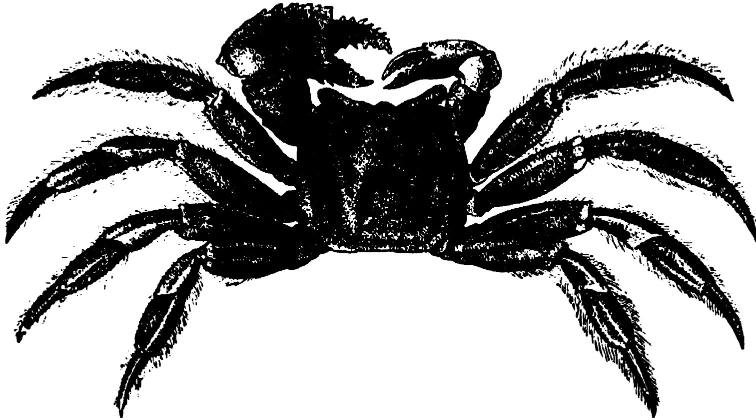
These crabs are generally found at a distance of from two to three miles from



INDIAN LAND-CRAB (⅔ nat. size).

the sea, where they spend the day under stones, or in other sheltered situations. Pairing takes place in the spring; and shortly afterwards the whole population makes a move for the sea, in which the females lay their eggs. When seized with this migratory instinct, nothing can turn them from their course. Issuing from hollow trees, from under rocks, and out of innumerable holes, they muster in a host so fast that they thickly cover an area more than a mile long, and upwards of forty yards wide. The males lead the way, and the band proceeds in a straight line to its destination, climbing over everything that comes in its road, be it hedges, houses, churches, hills, or cliffs, and rather clamber up at the peril of their lives than make a circuit. Having reached the sea, the females lay their eggs, and the young hatch out as miniature copies of their parents. At the time of moulting, which takes place late in the summer, the crabs retire to their burrows, close up the apertures, and remain there out of harm's way until the old shell is cast and the new integument hardened. It is while still in the soft state that these crabs, which are eaten by the natives, are considered most palatable.

The second family (*Ocypodidæ*) is typically represented by the swift land-crabs (*Ocypoda*), which appear to be less strictly terrestrial than the last, although unable to endure a long sojourn in the sea. Indeed, from the adoption of a land life their breathing-organs have become so modified that these crabs may be drowned

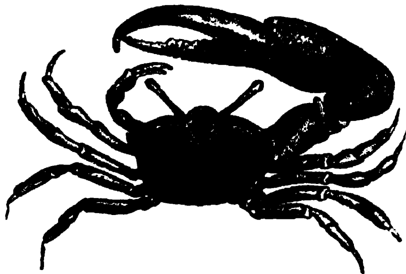


SWIFT LAND-CRAB (nat. size).

by an immersion of twenty-four hours. They frequent sandy beaches, and when chased run with such speed, as to make their capture a matter of difficulty. They burrow deep perpendicular holes in the sand. In these they stay when the tide is up, but at low water they wander over the beach in search of food, which consists of sand-hoppers or any offal cast up by the waves.

These crabs are gregarious, in the sense that numbers frequent the same spot. Each has a burrow to itself, and if one of them tries to enter by mistake the burrow of another, the rightful occupant makes a loud scraping noise to warn the intruder of its error; whereupon the latter retreats in search of its own abode. So strong is this instinct against trespassing, that a crab will always risk the chance of a fresh run for safety, rather than persevere in seeking concealment in the home of another.

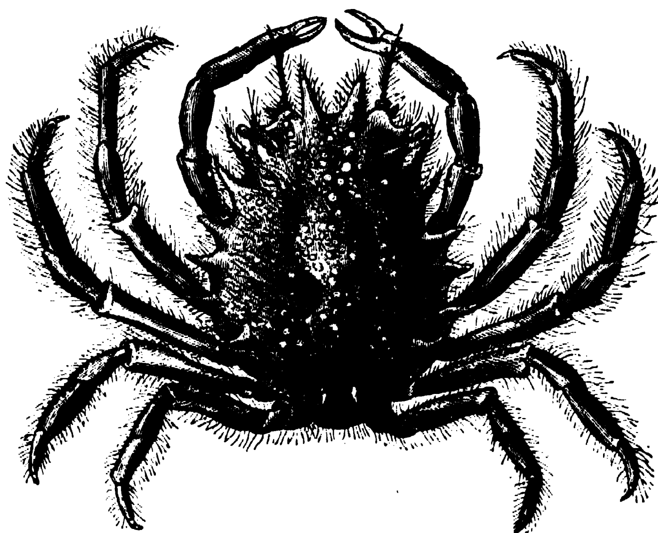
Nearly allied to the foregoing are the calling-crabs (*Gelasimus*), represented by a number of species from the warmer parts of the world. The carapace is broad and squared in front, and the long slender eye-stalks lie when at rest along its front border, sunk in the orbits. But the most remarkable characteristic is the enormous size of one of the pincers in the male; and it is from the habit of brandishing this claw, as if beckoning, that the name of calling-crab is derived. So abundant are these crabs, that they may frequently be seen by the thousands either running over the sand or peering out of their holes. These holes, which are thickly scattered over wide areas, lead into burrows frequently a foot or more in depth. The crabs scrape up a heap of sand, and grasping the pellet with three of the legs of one side, carry it to some distance before letting it



CALLING-CRAB (nat. size).

drop, then raising their eyes and peering round, dart back to the burrow, scrape together another heap, and persevere in the same manœuvre till the burrow is of the required depth. It was long supposed that the pincers of the male were used as weapons of attack and defence; but, in addition to its size, this limb is noticeable for its bright colours, and Mr. Alcock, who observed a number of males of an Indian species (*G. annulipes*) waving their large claws in the presence of a female, has suggested that their object in so doing is to make a display of their gaudy ornamentation and thus influence her choice of a mate.

The third family, *Grapsidæ*, contains species which for the most part are shallow-water forms. They are widely distributed, and attract the attention of travellers both on account of their bright colours and their extraordinary



THORNBACK CRAB (⅜ nat. size).

activity. Possessing long and powerful legs, tipped with sharp strong claws, they are able to dart amongst the rocks on the coast with amazing speed, while by means of their flattened carapace and limbs they can slip away into the narrowest clefts and chinks. Unlike the majority of the family, the little gulf-weed crab (*Planes minutus*) occurs in temperate and tropical seas, amongst the floating weed, and it is said that Columbus adduced its presence as an argument in favour of the proximity of land when his sailors were on the verge of mutiny. The crabs of the family *Pinnotheridæ* have the carapace soft and membranous and the orbits and eye-stalks small. An interesting fact connected with them is their habit of living in association with other animals; many species being found hiding between the shells of bivalve molluscs, and they have also been discovered lodged in the interior of sea-cucumbers. Entering this strange retreat in the zoæa stage, they never quit it of their own choice.

In the next tribe, Oxyrhyncha, the carapace is generally narrowed in front and wide behind, and furnished between the eyes with a distinct beak, which is

sometimes double and of great length. On its dorsal surface the carapace is usually roughened with spines or tubercles, and frequently furnished with hooked hairs. These crabs frequent deep water, and, at least, on the English coast, are regarded by fishermen as spiders. The characteristics of this group are shown in the figures of two British species, the thornback crab (*Maia squinado*) and the long-beaked spider-crab (*Macropodia longirostris*). Also belonging to this tribe is *Macrochira kæmpferi*, which is not only the largest crab, but the largest crustacean known. It inhabits the seas of Japan, and is said to be able to span eleven feet with its outstretched pincers.

A peculiarity of many of this group is their extreme untidiness, owing to the quantities of seaweeds, zoophytes, and other marine objects affixed to the carapace and limbs; and it has been ascertained that the presence of these extraneous bodies is not the result of chance, but that they are placed there, presumably for the purpose of concealment, by the crabs themselves. This feat they are enabled to perform owing to the flexibility of their pincers, and to the hooked hairs and spines with which the carapace is studded. Some examples of *Hyas*, deprived of their covering of foreign bodies, were placed under observation in an aquarium of which the bottom was covered with a layer of sponge. Contrary to their habitual sluggishness of manner, the crabs appeared much perturbed, running first to one side then to the other in the aquarium. Soon, however, by means of their pincers they tore off small fragments of the sponges, and, after first putting them to their mouths, placed them finally upon the dorsal surface of the carapace or limbs, sticking them there with a rubbing movement. Sometimes after several vain efforts the crab brought the fragment afresh to its maxillipedes and then repeats its efforts to make it adhere. The animal persevered in these manœuvres until the piece of sponge remained fixed in the spot where it wished to place it. By continuing to act in this fashion the crab succeeded in completely changing its appearance, and in rendering itself indistinguishable amongst the objects that surrounded it. The crab proceeded in exactly the same fashion when the bottom of the aquarium was strewn with seaweeds or any kind of zoophytes. Moreover, it was observed that some specimens, clothed with seaweed, which were left in an aquarium of which the bottom was covered with sponges did not hesitate to take off their old clothing and put on a new one of sponges.

The present tribe also contains the family *Parthenopidæ*, the species of which, although not armed with spines and hooked hairs for holding foreign objects, are yet protected in the midst of their surroundings, by having the carapace covered with pits and variously shaped depressions, giving it a roughened corroded appearance, and consequently imparting a resemblance to pieces of rock or fragments of dead coral.

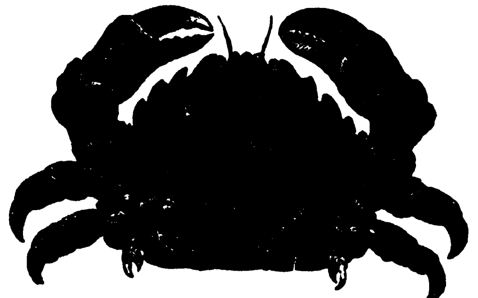
The sharp-nosed crabs, forming the tribe Oxystomata, are so called because the carapace is produced in front into a short beak-like prominence, while the external maxillipedes which cover the mouth are narrowed and pointed at the apex. The families belonging to this group present great diversity of structure and habits, the *Matutidæ* being active swimmers and resembling the *Portunidæ* in having their posterior legs transformed into flattened paddles, while the *Calappidæ*, which

live a sluggish life on the floor of the sea, have the sides of the carapace produced into shelf-like plates covering the legs, and the upper edges of the pincers supplied with large crests. The latter shut in the cephalothorax in front, so that when at

LONG-BEAKED SPIDER-CRAB (nat. size).

rest the whole animal is enclosed in a casing of shell, and resembles a smooth pebble on the sea bottom. Some of the species of the family *Leucosiidæ* are remarkable for the porcelain-like appearance and texture of the carapace, while in others, as in *Ebalia*, this plate is granular and corroded. Three or four species of the latter genus occur in British waters, but the majority of the Oxystomata are inhabitants of the tropics. In the genus *Dorippe*, belonging to the family *Dorippidæ*, the last two pairs of legs are short and raised on the upper surface of the body behind the carapace. In this position and structure they are adapted for carrying foreign bodies to serve as a protection.

The aberrant forms constituting the tribe Anomala differ from the other members of the suborder in having sometimes as many as fourteen pairs of gills, and also in that the apertures of the oviducts are situated upon the basis of the third pair of legs and

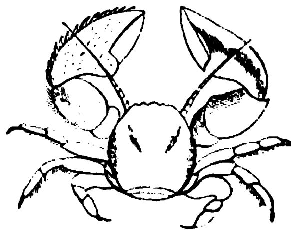


DROMIA CRAB (nat. size).

not upon the breast-plate of the cephalothorax. Moreover, as in the *Dorippidæ* of the preceding tribe, the last or last two pairs of legs are shorter that the rest, and dorsally placed, as shown in the illustration of the common *Dromia vulgaris*. The crab uses these limbs to hold foreign bodies like sponges and shells beneath which it thus lies concealed.

LONG-TAILED GROUP,—Suborder **Macrura.**

This suborder, comprising the lobsters, hermit-crabs, prawns, and shrimps, is distinguished by having the abdomen or tail usually of large size, and constituting a powerful flapper for swimming, in which function it is assisted by the enlargement of the appendages of its last segment to form with the telson a powerful tail-fin. The external maxillipedes are slender and leg-like, and the antennæ usually longer than the body. The first tribe, Anomura, contains forms which typically have a symmetrical tail. With these were originally classified the anomalous crabs, and there is no doubt that some of the species bear a striking resemblance to the latter. This is shown in the illustration of the broad-clawed porcelain-crab (*Porcellana platycheles*), which frequents rocks and seaweed at low water. It may be distinguished from the true crabs by its long antennæ, the presence of a tail-fin, and the slender unflattened external maxillipedes. The most familiar members are the hermit-crabs, which abound in all seas, and are represented by several British species. In the typical forms, the integument of the abdomen is soft; and, aware of its defencelessness, the hermit-crab invariably thrusts itself for protection into some empty shell, which it subsequently never willingly quits, save for the purpose of changing its abode for a larger one, when compelled by the exigencies of growth. It is not an uncommon thing to find shells containing a hermit-crab surmounted by a large anemone. The advantage to the crab of this association is considerable, for anemones are so distasteful that no fish will bite at them twice, and consequently a fish that would, under ordinary circumstances, greedily swallow a hermit-crab, shell and all, will not so much as sniff at it if protected by an anemone. One of the commonest deep-water British hermit-crabs, *Eupagurus prideauxi*, is invariably found associated with an anemone, but the latter adheres to the lower surface of the shell in such a manner that its mouth and tentacles are situated immediately below the forepart of the crab's body. It is thus able to share in the meals that the crab procures for itself, and the companionship is consequently mutually beneficial to the two. An advantage conferred upon the crab by the presence of the anemone results from the fact that the latter gradually absorbs the shell in which the former is lodged, so that there is no occasion for it to change its abode with growth, the soft tissues of the polyp offering no resistance to the crab's increase in size. Certain hermit-crabs have forsaken the sea as a permanent abode, and spend the greater part of their lives on land. For instance, the genus *Cenobita*, which occurs both in the West Indies and India, may be met with in forests far from the coast. The best known of these

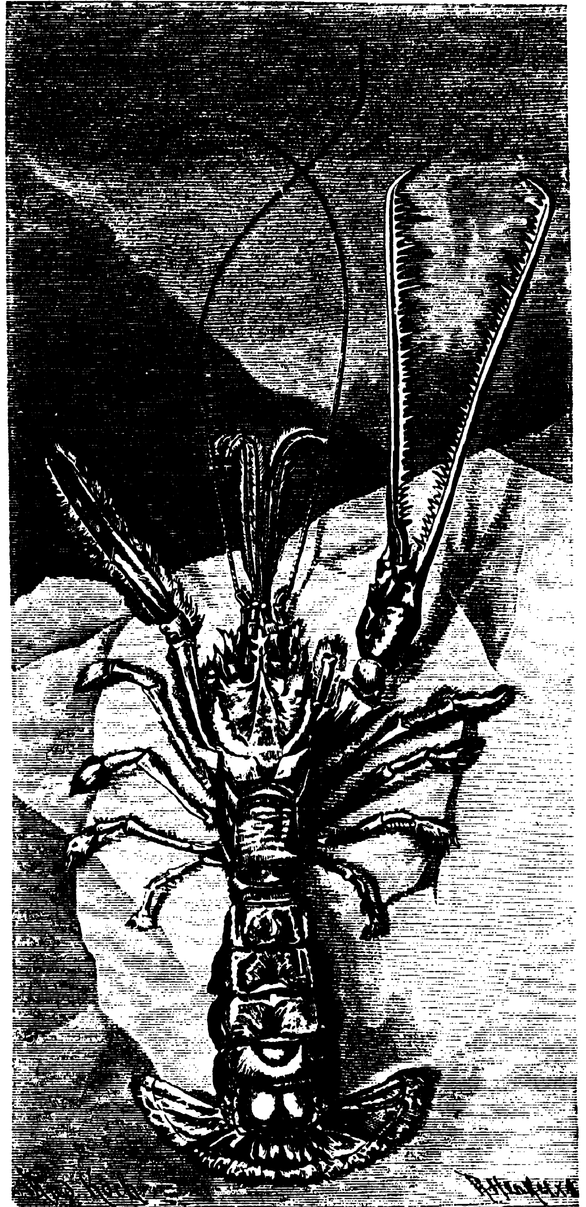


BROAD-CLAWED PORCELAIN CRAB (nat. size).



HERMIT CRABS.

terrestrial forms is the great cocoa-nut crab (*Birgus latro*), found in the islands of the Indo-Pacific seas, and remarkable not only for its great size and habits, but also for having the abdomen symmetrical and covered above with a series of horny plates. These animals inhabit deep burrows, which they hollow out beneath the roots of trees, and carpet with fibres stripped from cocoa-nuts. Periodically, however, they are compelled to visit the sea to moisten their gills; and here they lay their eggs, the young being hatched and living for some time on the coast. They live principally upon cocoa-nuts, which fall from the palms, but they do not climb the trees after the fruit. To get at the contents of the nut, the crab first tears away the fibre overlying the three "eyes," and then hammers away with its claws at the latter until a hole is made, when it extracts the kernel by means of its smaller pincers. Some observers state that after drilling through the perforated eye, the crab grasps the nut in its claws and breaks it against a stone.

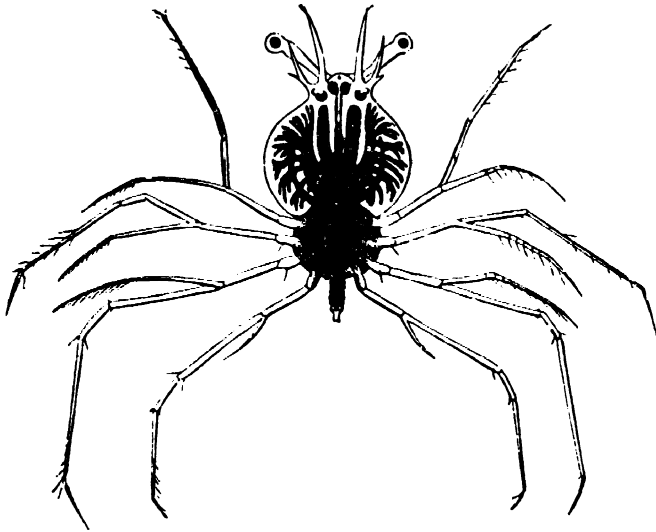


ONE-CLAWED LOBSTER, *Thaumastocheles zeleuca* (nat. size).

In the next tribe, or Thalassinidea, the carapace is much compressed and has a small rostrum, but the abdomen is well developed and often wider in the middle than in front. As in the short-tailed group, the fourth pair of thoracic limbs are enlarged and generally completely chelate, while the four succeeding pairs, of which the last is smaller than the rest, usually terminate in simple claws. All the members of this group are exclusively marine, living at the bottom of the sea buried a foot or more in the mud. The accompanying figure represents a species (*Thaumastocheles zeleuca*) obtained at a depth of four hundred fathoms in the West Indies. It is characterised by the extraordinary development of the pincers of the right claw, which are not only very long and slender but beset with spine-like teeth. The creature is totally blind, having lost both eyes and eye-stalks.

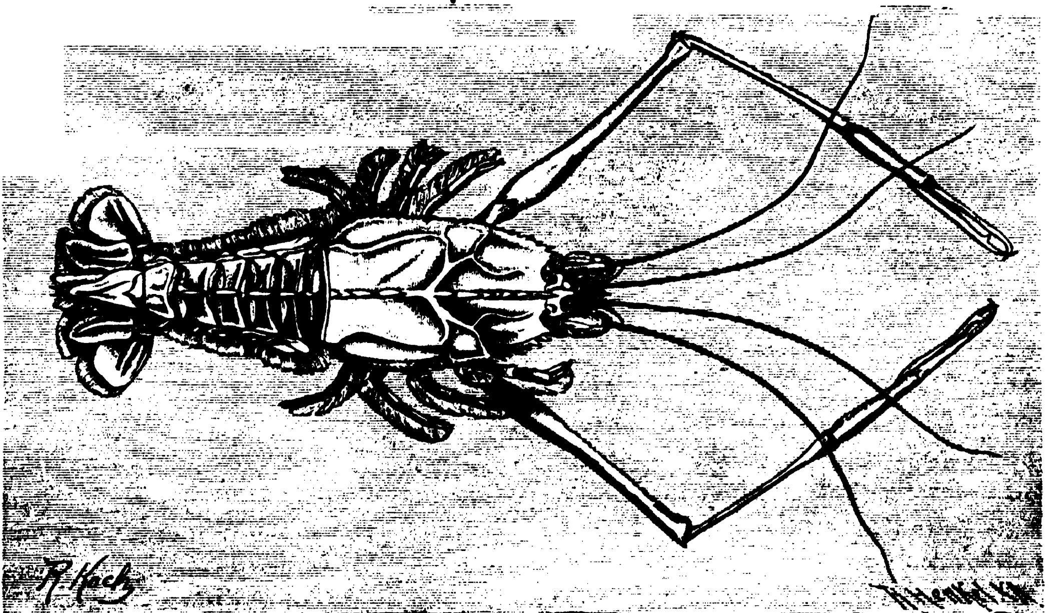
In the tribe of the Scyllaridea none of the limbs of the thorax are truly chelate,

and the antennæ are not furnished with an external scale-like basal piece. The best known members of this group are the *Palinuridæ*, or rock-lobsters, one member of which, the crawfish (*Palinurus vulgaris*), may be seen for sale in England. It is larger than the lobster, and has enormously long stout antennæ, and a spiny carapace but no claws. This species is figured on the left side of the coloured Plate. The second family, *Scyllaridæ*, contains a considerable number of genera (*Scyllarus*, *Ibacus*, etc.), mostly from tropical seas, remarkable for having the carapace broad and flattened, with the eyes enclosed in complete orbits on its upper surface, and the antennæ short and scale-like. In this tribe the larvæ are unlike those of crabs or lobsters. On account of their transparency and delicacy they are called glass-crabs. The body is formed of three distinct parts, a large round-sided head, a smaller but also round-sided thorax, and a minute jointed abdomen which projects like a short tail from the hinder end of the thorax. The abdomen bears no limbs.



LARVA OF CRAYFISH, THE SO-CALLED GLASS-CRAB (nat. size).

The lobsters and crayfish (Astacidea), have at least three pairs of the large thoracic limbs pincer-like, the first being much larger than the others. The



SLENDER-CLAWED CRAYFISH, *Willemœsia leptodactyla* (nat. size).

antennæ are furnished with a distinct basal scale-like plate. The first family (*Eryontidæ*) contains several genera found in deep water in various parts of the world, the slender-clawed *Willemœsia leptodactyla* occurring in both the Pacific and Atlantic Oceans, at depths varying from thirteen hundred to over two thousand fathoms. As in many deep water species the eye-stalks are rudimentary. The five posterior pairs of thoracic limbs are chelate in both sexes, and the first pair of antennæ have their inner branches long, while the carapace is flattish with a small rostrum.

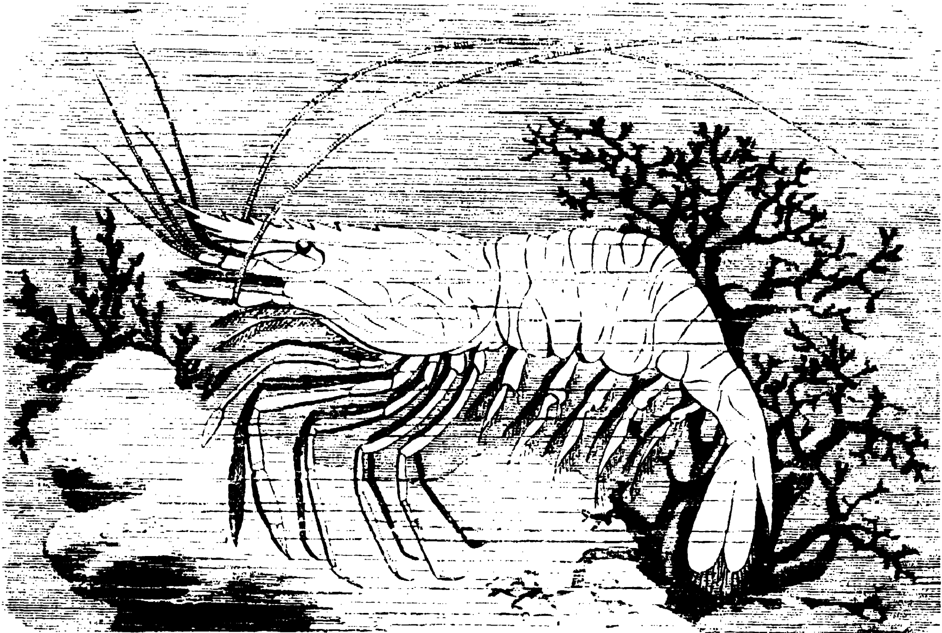
The remaining three families, namely, the *Nephropsidæ*, or lobsters, the *Potamobiidæ*, and *Parastacidæ*, or true crayfish, are nearly allied. Among the



COMMON CRAYFISH (slightly reduced).

former, the Norway lobster (*Nephrops*) is smaller than the common lobster, and has the pincers long, slender, and covered with scale-like tubercles. The common lobster (*Astacus gammarus*), from a commercial point of view, is one of the most important Crustaceans. The crayfish (*Potamobiidæ*), which live exclusively in fresh water, are very like small lobsters; the species known as *Potamobia fluviatilis* being found in many streams in England. Throughout the day crayfish usually lurk under stones or the edge of banks, and creep out in the evening in search of food, which consists of worms, water-insects, small frogs or fish, and plants and roots of many kinds. During the winter they seek the shelter of crevices or

excavate deep burrows in the banks. In these they lie, with their antennæ stretched forward, and their claws ready to seize any passing object that may serve for prey. Pairing takes place in the autumn, and the female retires to her winter-quarters to deposit her eggs, which vary in number from one to two hundred. After being laid, the eggs are attached to the abdominal limbs of the mother. During the winter they develop slowly and are not ready to hatch until late in the spring or the early summer. The young, which at first much resemble the parent and go through no metamorphosis, adhere tightly to their mother's limbs, and do not leave her until able to shift for themselves. Growth, however, although fast at first is a slow process, the crayfish not reaching maturity until about five years after birth. They probably live under favourable conditions for

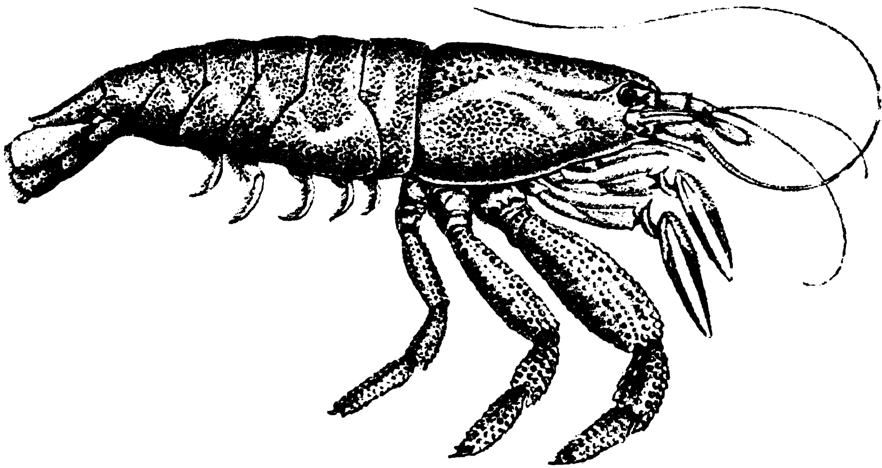


COMMON PRAWN (nat. size).

about fifteen or twenty years. Although not considered a delicacy in England, on the Continent and especially in France, they are much appreciated. It is said that in Paris alone from five to six million crayfish are consumed annually, and to meet the demand large numbers are imported from Germany and elsewhere, and artificial cultivation has been carried on with success. The crayfish belonging to this family are found in the Northern Hemisphere; but in the Southern Hemisphere several forms occur which are referred to another family, *Parastacidæ*, differing in the arrangement of the gills. Some of these forms are of large size, the Tasmanian *Astacopsis franklini* measuring a foot or more in length.

The next tribe, Caridea, embraces the shrimps and prawns, in which the last three pairs of thoracic limbs are never chelate, although the two pairs in front of them are frequently so. The tribe is divided into three sections. The first of these, or Crangoninea, contains the family *Crangonidæ*, or shrimps, characterised by having the first pair of trunk-limbs subchelate, that is, with the terminal segment

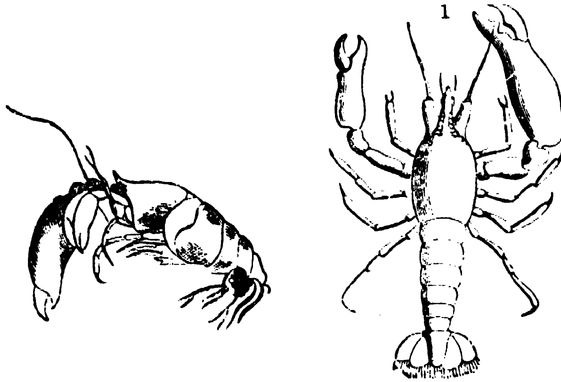
capable of being folded back upon the penultimate. The common shrimp (*Crangon vulgaris*) occurs in shallow water on sandy coasts of temperate countries of the Northern Hemisphere. Its colour is a speckled grey, corresponding closely with that of the sandy sea-bottom upon which it lives, and in which it buries itself when threatened with danger. To escape the vigilance of fish, shrimps resolutely keep themselves hidden during the day, but come forth at night to hunt for food. The presence of this they perceive by means of scent, since a blind shrimp will find food as quickly as an uninjured one. A second British species is Allman's shrimp (*Crangon allmani*), abundant in deep water in the Irish Sea and on the west coast of Scotland. It may be at once distinguished by the presence of two fine keels on the upper side of the sixth segment of the abdomen. Both have a short rostrum and no spines on the carapace; but some of the other members of the family have crests of spines on the carapace, and sometimes a largish rostrum as in the Arctic *Sclerocrangon boreas*. In *Rhynchocinetes typus*, from the South Pacific,



WEST INDIAN PRAWN, *Atya* (nat. size).

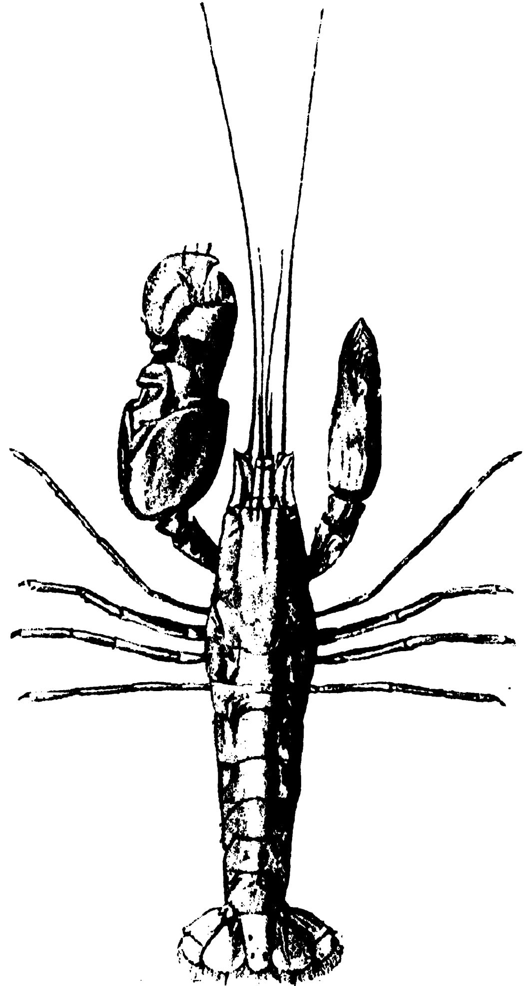
this rostrum is not only large but movably jointed to the carapace. The section Monocarpinea differs from the last in having the first and second trunk-limbs completely chelate, and the second pair larger than the first. To this section belong a number of fresh- and salt-water forms, and amongst them the *Palæmonidæ* or prawns. The general form of the body is shown in the figure of the common prawn (*Leander serratus*). In its native haunts the prawn is nearly invisible, being almost colourless, translucent, and marked merely with streaks of various tints. In the rivers of tropical countries occur prawns (*Palæmon*) rivalling lobsters in size, and remarkable for the length of their pincers, which may exceed that of the body. Among the largest are *P. jamaicensis* from the West Indies and Central America, and the Indian *P. lar*, so much esteemed when cooked as a curry. Also belonging to the same section is the family *Atyidæ*, containing a few genera such as *Atya* and *Caridina*, found in both Eastern and Western Hemispheres in fresh-water streams and lakes. In *Atya* the trunk-limbs are curiously constructed, the first two pairs being short and subequal with the two fingers of the pincers tipped with a long tuft of hairs. The remaining three pairs, of which the first is much the

stoutest, end in simple claws, and are studded with scale-like or spiny tubercles. It feeds on the organic matter contained in the mud which it gathers up in its nippers, compresses into pellets, and transfers to its mouth. The two small Crustaceans figured in the illustration belong to the family *Pontoniidæ*. Both are semiparasitic in habits, *Pontonia* living between the valves of mussel shells, and *Typton* being a lodger in sponges.



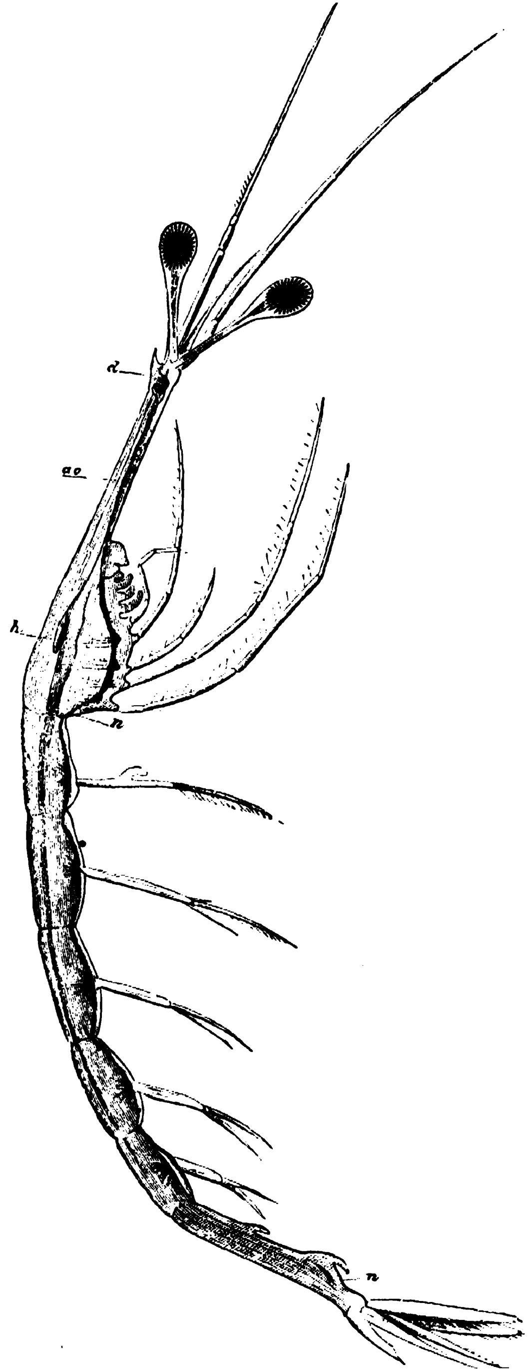
1, MUSSEL-PRAWN (*Pontonia tyrrhena*); 2, SPONGE-PRAWN (*Typton spongicola*). (Nat. size.)

The Polycarpinea contains those species in which the wrist of the second pair of trunk-legs is divided into several secondary segments. In other respects they are nearly allied to the last group. A common British representative is the red shrimp (*Pandalus montagui*), which gives its name to the family *Pandalidæ*, and is abundant upon many parts of the British coasts. This tribe is abundantly represented in tropical seas by the hooded shrimps (*Alpheidæ*), remarkable for the concealment of the eyes beneath the edge of the carapace, and for the enormous size, bright colours, and peculiar shape of the right or left pincers. With this instrument the hooded shrimps, which frequent holes and crevices in the coral-reefs, are able to produce a clicking sound when angry or alarmed by the approach of danger. The last tribe of the suborder, known as Penæidea, appear similar to the Monocarpinea, but may be distinguished by the circumstance that the first three pairs of trunk-limbs are chelate, so that only the posterior two terminate in simple claws. Some of the species of the genus *Penæus*, belonging to the family *Penæidæ*, attain a large size in tropical seas, and form an important article of commerce. Nearly allied is the little *Spongicola venusta*, which makes its home in glass-sponges. In this neighbourhood may be placed the anomalous



HOODED SHRIMP, *Alpheus* (nat. size).

family, *Sergestidæ*, in which the gills are impoverished or lost, while the first pair of trunk-legs and sometimes the second are simple, the chelæ of the third are minute, and the fourth and fifth pairs are feeble, rudimentary, or absent. To this family belongs the genus *Leucifer*, remarkable for having the eyes and antennæ supported at the end of a long neck which extends in advance of the mouth. The gills are absent, respiration being effected by means of the general integument, which is so thin that the internal organs can be seen. In the figure the dark line (*n*) is the ventral nerve-chord which throws out finer branches from ganglionic swellings in each of the segments; (*h*) is the heart, while immediately below the latter is the stomach, passing forwards into the gullet and backwards into the intestine.



LONG-NECKED SHRIMP, *Leucifer* (much enlarged).

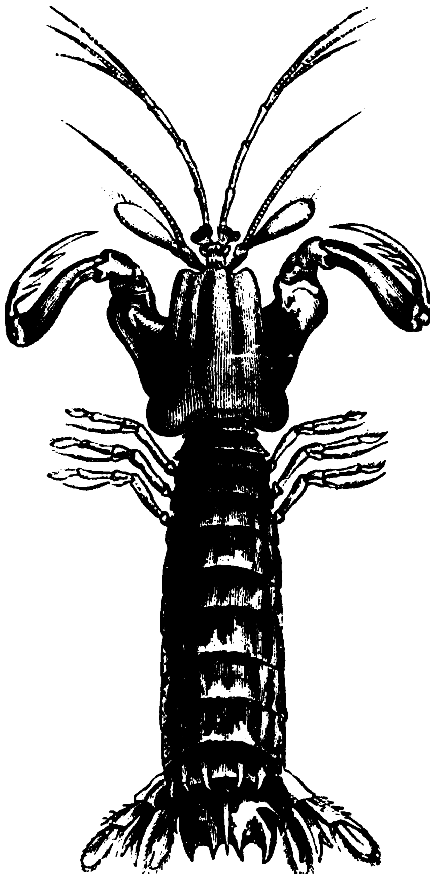
CLEFT-FOOTED GROUP,—Order SCHIZOPODA.

This name is applied to a group nearly allied to the long-tailed Decapods; the chief difference between them being in the fact that in the present order the eight thoracic limbs are similar in structure, each being pediform and provided with a distinct exopodite on the second segment. The gills, which are attached either to the thoracic or abdominal appendages, generally project into the water, and are but rarely concealed in a chamber. The eggs are carried by the female beneath the trunk, and are frequently protected by the development of a pouch. The order contains several families embracing a large number of mostly marine forms, some of which occur at great depths. Of the British species, the finest is *Nyctiphanes norvegica*, which forms an important part of the food of herrings. It has luminous organs on the thorax and abdomen, and when swimming in a glass vessel, in a darkened room, appears like a flash of light. The young, as in all the members of the family

Euphausiidæ, are hatched in the Nauplius stage. Most Schizopods are small, but species belonging to the genera *Lophogaster* and *Gnathophausia* measuring as much as 6 inches in length have been obtained. To the family *Mysidæ* belongs the genus *Mysis*, or opossum-shrimps, among which is *M. veheta* from certain lakes in Northern Europe. Into these lakes the species is presumed to have entered while they were connected with the sea; a supposition borne out by the fact that it is nearly related to *M. oculata*, now living in the Arctic Ocean.

THE MANTIS-SHRIMPS,—Order STOMATOPODA.

The mantis-shrimps (*Squillidæ*), which owe their name to the resemblance that their seizing limbs bear to those of the insect mantis, are abundant in tropical seas, where they sometimes reach a large size. Although bearing a general likeness to the long-tailed Decapods, they may be recognised by certain prominent characters. A glance at the accompanying figure will show that the carapace is so short as to leave the hinder segments of the thorax uncovered, and, since the gills are attached to the abdominal limbs, it forms no branchial chamber. Only three pairs of limbs are modified into jaws, these being the mandibles and two pairs of maxillæ. The remaining eight pairs of thoracic limbs are foot-like, the large prehensorial pair corresponding to the second maxillipedes of a Decapod. Two kinds of mantis-shrimp are occasionally met with in the English Channel, namely, *Squilla desmaresti* and *S. mantis*. The former is not uncommon along the shallower parts of the shores of Jersey, but as it lives in deep burrows among the roots of sea-grass, in a zone never uncovered by the tide, its appearance is infrequent. The allied North American *Lysiosquilla excavatrix* is found in the sand below low-water-mark, where it is protected from the full force of the ocean swell, and inhabits deep cylindrical burrows which are nearly vertical and go down for several feet.



MANTIS-SHRIMP (reduced).

Sessile-Eyed Series,—EDRIOPTHALMATA.

We now come to the second great series of the Malacostraca, in which the compound eyes are generally sessile, and never mounted on movable stalks. As a rule, the last seven segments of the thorax are not covered by the carapace, and the last four are always free. The first order, Cumacea, is in many respects inter-

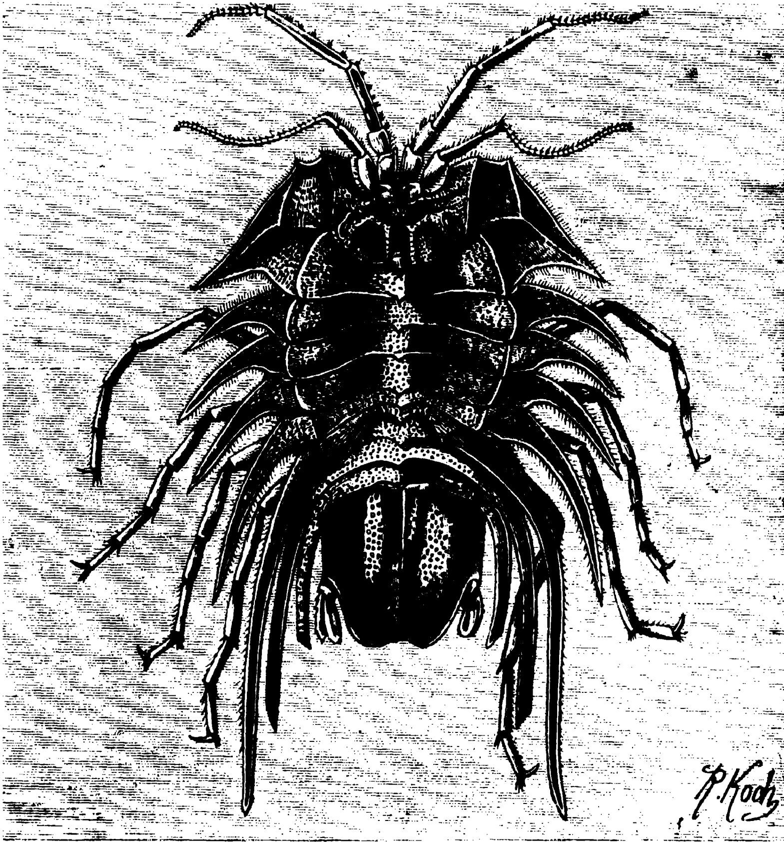
mediate between the typical members of the last and present series, the thorax being larger and broader than the abdomen, while the carapace covers all but the last five segments. The front angles of the carapace are produced to meet in a kind of beak in front of the head, and the eyes are generally united in a single cluster of ocelli. None of the thoracic limbs are prehensile or chelate. The first five segments of the abdomen have no appendages in the female, although such limbs are present in the male. In the sixth segment appendages are present in both sexes, and form a fork-like termination to the body. Two of the best known genera of the group are *Cuma* and *Diastylis*. The order, however, is relatively a small one, containing only a little over a hundred species. It has, nevertheless, a wide distribution, forms being met with in shallow and deep water in all seas, although the Arctic Ocean produces individuals of the largest size and in the greatest abundance.

Order Isopoda.

Unlike the last, this second order of the series exhibits great diversity of structure. As a rule, the posterior seven segments of the thorax are free, and at least the first three, and generally the first five segments of the abdomen are short and sometimes fused together, while the sixth is the largest, and bears the telson and a pair of appendages. The other abdominal appendages usually overlap, and are modified to act as gills. The seven thoracic limbs are generally large, and perform the function of walking or swimming organs, while the posterior five pairs at least have no exopodites. There are four pairs of jaws, namely, the mandibles, two pairs of maxillæ, and one pair of maxillipedes. Although there are many exceptions, it may be said that, as a rule, the body is broad, short, and flattened. Corresponding to the structural variations, the Isopods exhibit great diversity of habits and habitat. Most are marine, occurring in shallow waters or at great depths. Some live in fresh water, others on land, while others have taken to a parasitic life, and have thus to a great extent lost the characters of the order.

Of the five tribes, the Valvifera have the posterior pair of abdominal appendages, or uropods, transformed into valves or flaps, covering part of the lower surface, and constituting a chamber for the gills. The tribe contains two families, the *Arcturidæ* and *Idoteidæ*. The former are distinguished by their slender cylindrical shape, long lower antennæ, and the length of the fourth thoracic segment, which separates the posterior three pairs of thoracic legs from the anterior pairs by a wide space. The anterior thoracic feet are slender and hairy on the inner side, while the posterior feet are strong and prehensile, and enable the animal to fix itself to the branches of corallines. In the *Idoteidæ* the body is longish and narrow, the thoracic segments being all of about the same size and shape, and their appendages short, stout, and used for walking. The anterior segments of the abdomen are short, and the posterior fused into a caudal shield. The species of the genus *Idotea* live in shallow water, and frequent places where there is an abundance of decomposing seaweed. They are essentially carnivorous, feeding on dead fish, worms, and molluscs.

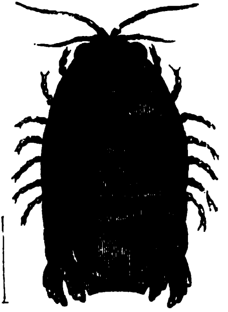
The tribe Flabellifera contains a part of marine species, in which the abdomen terminates in a tail-fin, formed as in the macrurous decapods from the telson and the limbs of the last segment. There are too many families to mention, but some of the characteristic forms are shown in the accompanying illustrations. In the genus *Serolis*, which alone represents the family *Serolidæ*, the body is depressed and broad, the segments of the thorax being furnished with long pointed side-plates, which impart to the animal a superficial resemblance to a trilobite. The legs and two pairs of antennæ are long. It is stated that the *Serolidæ* "live by preference on sandy ground, into which they burrow with their flat bodies up



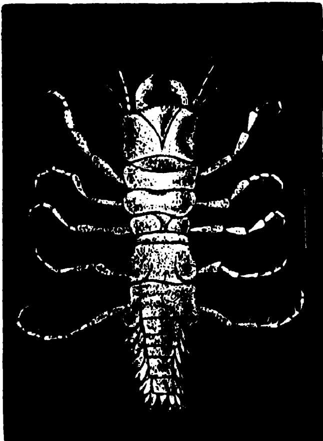
Serolis bromleyana (nat. size).

to the caudal plate. Their nourishment appears chiefly to consist of the organic materials distributed in the fine sand, diatomacea and organic detritus. Their locomotion is carried on less by swimming than by backward movements on the sandy ground, wherein the widely separated feet are used as a point of support." The species figured (*S. bromleyana*) is the largest, and has been taken at a depth of nineteen hundred and seventy-five fathoms. In the *Sphæromidæ* the convex body is capable of being rolled into a ball. Several species of *Sphæroma* occur on the coasts of Britain, and may be found, sometimes in numbers, sometimes isolated, beneath stones or amongst seaweed at low water. The next family (*Gnathiidæ*) contains the genus *Gnathia*, in which the males and females are so

dissimilar that they were referred to two families. In the adult male the mandibles are powerful and prominent, and the head is large, squared, and at least as wide as the thorax. In the adult female, on the contrary, the head is small and triangular, without visible mandibles, and the thorax is much dilated. Many species are known from the European coasts, and one has been obtained at a depth of nine hundred fathoms. Belonging to this tribe, but representing a family by itself, is *Limnoria lignorum*, known to fishermen as the gribble, which is a persistent destroyer of submerged wood. The creatures are about one-sixth of an inch long, and of an ashy grey colour; and the destruction they bring about is due to their habit of boring into timber below water-mark. They are vegetarians, and feed on the wood which they excavate. The members of the group known as fish-lice are mostly of large size, the body being longish and oval, and the antennæ fixed on the front of the head, which bears in addition two large eyes. The anterior three pairs of thoracic limbs are stout and prehensile, terminating in strong curved claws, while the posterior four pairs are longer and thinner, and adapted for crawling. By means of their powerful fore-feet the *Cymothoidæ* attach themselves to both marine and fresh-water fish, and have a liking for the inside of the mouth of their hosts.



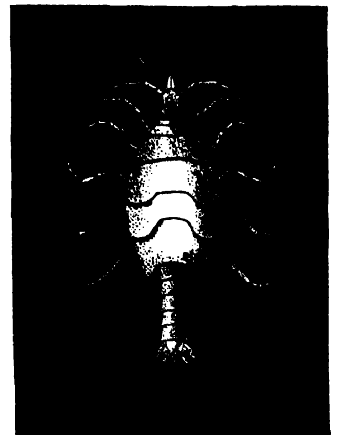
Sphæroma (enlarged).



MALE GNATHIA (enlarged).

Another tribe is the Epicaridea, the members of which live parasitically upon other crustaceans. The form of the body in the female is, as a rule, distorted and unsymmetrical; but the smaller males are symmetrical, and are usually found adhering to the females. No group of Crustaceans seems exempt from the attacks of these parasites, but it is said that each species has its peculiar kind.

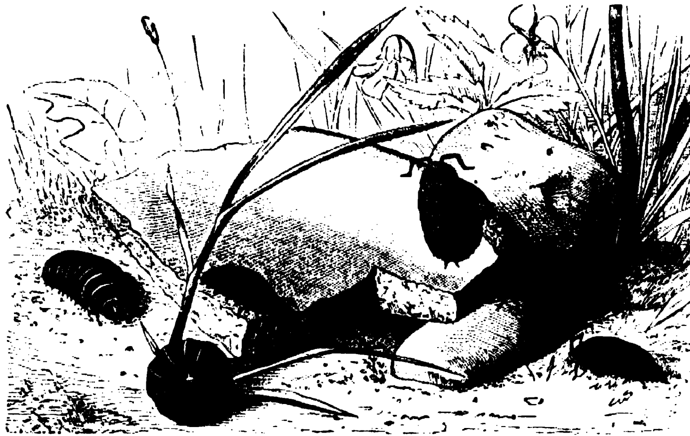
The best known example of the tribe Asellota is *Asellus aquaticus*, distributed in fresh-water ponds and ditches almost all over Europe The creature is of a greyish colour, mottled with paler markings; and the male, which is longer than the female, measures about half an inch long. The body is long, narrow in front, with a small head, and the antennæ of the second pair are about as long as the body and head taken together. The seven segments of the thorax are free and of large size, but those of the abdomen have coalesced into a plate, from the end of which the long slender forked uropods project. The seven thoracic limbs are long, slender, and increase in length from the first to the seventh.



FEMALE GNATHIA (enlarged).

The tribe Oniscoidea contains the wood-lice, in

which the abdominal appendages are modified for breathing air. Like all crustaceans that have adopted a terrestrial life, they seem able to live only in air saturated with moisture. The body is usually broadly oval, convex above, and flat or hollow beneath, widest in the middle, and gradually narrowing towards the head and tail. The head is small, but the thorax large and seven-jointed, the abdomen being short. Representatives of this tribe are found in all quarters of the globe. A familiar British species is the sea-slater (*Ligia oceanica*), a large species living amongst the stones and rocks upon the coast above high water. The creature is nocturnal, and unless disturbed is not often seen during the day, but issues from the cracks and clefts of rocks in numbers at night. More obtrusive are the common wood-lice *Porcellio scaber* and *Oniscus asellus*, the former distinguishable from the latter by its duller colour and the granules upon its segment; *Oniscus* being smooth and more or less variegated. Both these are rather flat, and incapable of rolling up into a ball; but the pill wood-louse (*Armadillidium vulgare*) has the dorsal surface more convex, and when handled rolls up into a ball. On account of their resemblance to pills, these creatures were used for various maladies. In addition to its rounder shape, the pill wood-louse may be recognised by the fact that the appendages of the last abdominal segment (the uropods) do not project like a couple of small tails from the hinder end of the body. Members of this group, differing but little from the species described, are widely distributed in all temperate and tropical parts of the world.

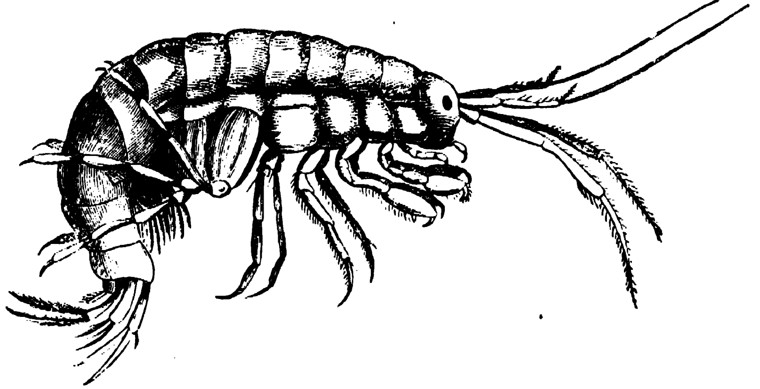


COMMON AND PILL WOOD-LICE (nat. size).

The tribe Phreatoicidea can only be briefly noticed. It contains the genus *Phreatoicus*, of which two species—both inhabiting fresh water—are known, one from New Zealand, and the other from Australia. The body is long and laterally compressed, the seven thoracic appendages are well developed, and the first is subchelate as in many Amphipoda, and the abdomen consists of six distinct segments, with the gills attached to its appendages. The last tribe, Chelifera, containing the genus *Tanais* and others, approaches the next order, and is distinguished by having the first pair of appendages following the jaws—that is the second maxillipedes—pincer-like. It further differs in that the abdominal limbs are used rather for swimming than for respiration; the breathing-chamber is situated in the posterior portion of the thorax, and a constant circulation of water is kept up within it by the movement of a process projecting backwards from the maxillipedes.

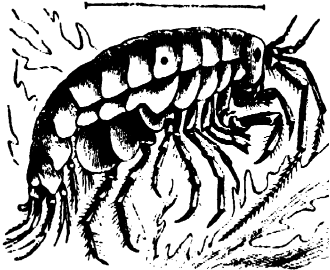
Order AMPHIPODA.

The Amphipods are allied to the Isopods, but the majority are recognisable by having the body narrow and flattened from side to side, instead of broad and flattened below. Moreover, the gills are attached to the thoracic feet, and the latter, instead of being broad, leaf-like, and overlapping, are foot-like, elongate, and used for leaping or swimming.

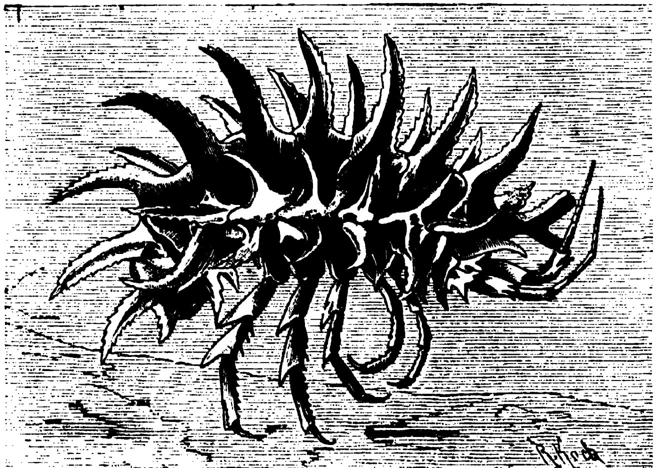


FRESH-WATER SHRIMP (enlarged).

In the suborder Gammaridea the eyes are mostly of small size, and seldom prominent. The head does not coalesce with the first segment of the thorax, and the maxillipedes have a distinct palp; the abdomen being well developed, and bearing appendages. The form of the body is shown in the illustration of the fresh-water shrimp (*Gammarus pulex*), and the sand-hopper (*Talitrus locusta*). The latter lives near the edge of the sea, beneath seaweed, or other substances, which prevent the evaporation of the moisture from the sand. Sand-hoppers usually progress on land by leaps; and although some nearly allied forms are found far from the sea, the majority of the Gammaridea are marine, swimming by means of the constant play of their abdominal appendages, and, when thrown on the land, wriggling helplessly along on their sides. The fresh-water shrimp is common in the streams and ditches of Europe. During the cold months of the year they bury themselves in the mud, but emerge from their winter-quarters on the first warm days of spring. Amongst deep-water forms, perhaps the most noteworthy are *Acanthechinus tricarinatus*, and *Andania gigantea*. The former has developed a spiny process at almost every possible point, each of the

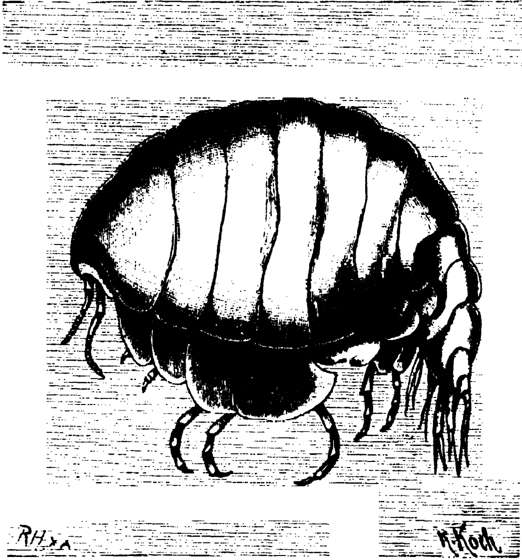


SAND-HOPPER (enlarged).



SPINY SHRIMP, *Acanthechinus tricarinatus* (nat. size).

principal segments bearing three large and pointed spines, which have their edges armed like the blades of a saw. Very different is *Andania*, which is one of the largest of amphipods, reaching a length of 2 inches. Many members of the group construct tubular dwelling-places, in which they take shelter, and lay their eggs. For instance, the British *Amphitha rubricata*, which is a brilliant crimson colour, builds a nest of particles of seaweed cemented together with threads; while another species of the same genus (*A. littorina*) makes a tube by cementing together the edges of a leaf of growing weed, so as to make a tube open at both ends. Again, according to Bates, *Podoacerus capillatus* "builds its nest in a very bird-like manner in submarine forests; the nests consist chiefly of fine thread-like material, woven and interlaced, being established firmly in the branches of zoophytes; some small extraneous fragments are often bound with it, but these appear more the result of accident than intention. The form of the nest is somewhat oval, the entrance being invariably at the top. These nests are evidently used as places of refuge."



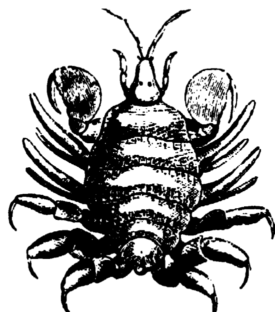
GIGANTIC ANDANIA, *Andania gigantea* (nat. size).

In the tribe Caprellina the head has coalesced with the first segment of the thorax, and the abdomen is reduced in size, with most of its appendages wanting. The two principal families are the *Caprellidæ*, or skeleton-shrimps, and the *Cyamidæ*, or whale-lice. In the former the thorax is cylindrical, and the abdomen, with its limbs, rudimentary. In the typical *Caprella* the third and fourth thoracic segments are without legs, but bear a pair of branchial vesicles; the appendages of the second pair are developed into claspers, and those of the three last pairs are of the ambulatory type. These shrimps seldom swim, but climb amongst the branches of seaweeds and zoophytes. When at rest, they grasp the stems of the weeds with their hind-limbs, and, holding the body in an erect position, wave their long antennæ in search of prey. In the whale-lice, which live parasitically upon cetaceans, the short and conical head is united to the first segment of the thorax, which consists of six free, flattened segments. As in *Caprella*, the third and fourth segments of the body bear no limbs, but are furnished with a pair of gills, usually turned over the animal's back. In the



SKELETON-SHRIMP (somewhat enlarged).

female, these segments carry beneath them plates, forming sacs, for the eggs. The second, fifth, sixth, and seventh segments are provided with short limbs, terminating in a sharp, pointed segment, which closes against the enlarged penultimate segment as the blade of a pocket-knife closes on its handle. By means of these chelate appendages the animals fasten themselves to the skin of cetaceans, thrusting their sharp claws into the epidermis, and adhering so firmly as to be able to withstand the dash of the waves.

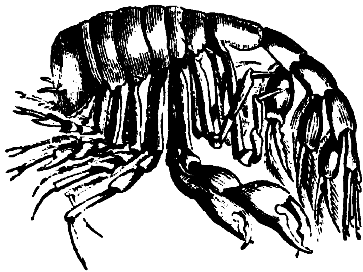


WHALE-LOUSE, *Cyamus* (nat. size).

The members of the tribe Hyperina differ from the last by the larger size of the head, the more prominent eyes, and the absence of a palp on the maxillipedes. To this tribe belongs the large *Cystosoma*, a pelagic animal, probably retiring during the day to a considerable depth, but occasionally coming to the surface. The animal is colourless and transparent, so that by transmitted light the internal organs can be seen. The head is large and inflated, with its upper surface occupied by two enormous eyes. The genus *Phronima* also contains species attaining a considerable size, examples of the European *P. sedentaria*

TRANSPARENT OCEAN-SHRIMP, *Cystosoma neptuni* (reduced).

exceeding an inch in length. As in *Cystosoma*, the second pair of antennæ are obsolete; the head is large, with the eyes placed upon its summit. There are seven pairs of large thoracic appendages, the third from the end forming a large and strong pincer.



PHRONIMA (enlarged three times).

The species are widely distributed, although most abundant in the tropics. Like many pelagic animals, they are translucent, and mostly live in the mantle-cavity of the ascidians *Pyrosoma* and *Doliolum*, where the eggs are laid, and the young hatched.

To a certain extent connecting the Malacostraca with the Entomostraca is a group of Crustaceans known as the Leptostraca, and containing the three recent genera *Nebalia*, *Nebaliopsis*, and *Paranebalia*, and a number of fossil forms. The affinities of the group seem to lie with the Phyllopods on the one hand, and the Schizopods on the other. The body is laterally compressed, and the whole of the cephalothorax and the first four segments of the abdomen enveloped in a carapace, which springs from the head, and is formed of two movable valves, closed by a muscle. Although the eight thoracic segments are overlapped by the carapace, they are distinct and movable. The abdomen consists of eight movable segments, or two in excess of the normal number; but there are only nineteen pairs of appendages. The head bears a small, movable rostrum, and a pair of stalked eyes. The two pairs of antennæ are well developed, and there are three pairs of jaws. The appendages of the thorax are foliaceous. The members of this group are marine, and widely distributed, being found in cold and warm latitudes. The female carries the eggs attached to her thoracic feet.

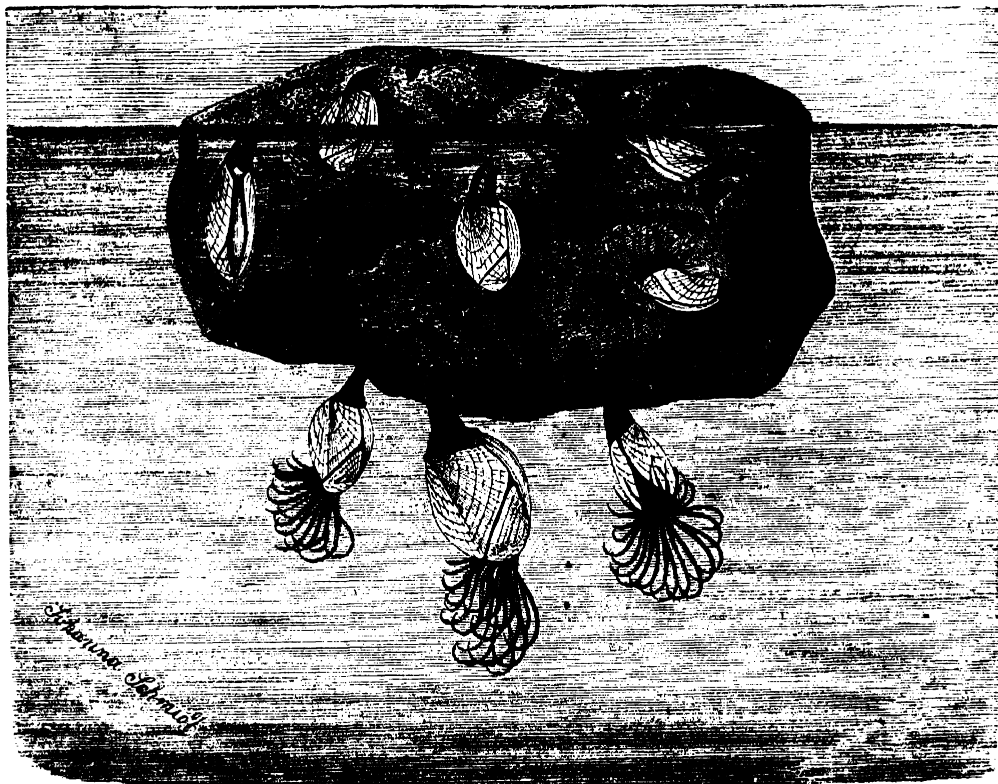
Subclass Entomostraca.

The Crustaceans of this division are small, and vary much more than the Malacostraca, from which they differ in the following features. The number of body-segments is not constant, but either greater or less than nineteen, and, as a rule, there are no appendages to the abdomen. In the majority of cases the young are hatched as a Nauplius.

The Barnacles,—Order Cirripedia.

The adult members of this group are so unlike typical Crustaceans that it can hardly be a reproach to the older naturalists that they failed to discover their affinity. Two well-known members of the order are the barnacles so frequently attached to the bottoms of ships or floating timber, and the acorn-barnacles covering the rocks on the coast. The barnacle (*Lepas*) consists of a tough longer or shorter stalk, one end of which adheres tightly by means of a cement to the timber or ship, while to the other is attached an oval compressed body encased in pieces of shell, through two of the valves of which can be protruded six pairs of slender, bristly, two-branched, filamentous limbs. These limbs, being the appendages of the thorax, keep up a constant sweeping motion, whereby particles of food are

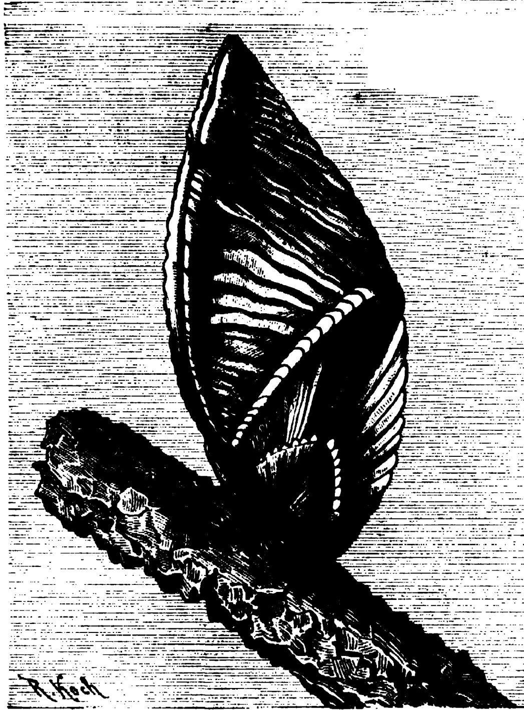
washed into the mouth that lies below them. The abdomen is undeveloped; but the rest of the body is enveloped in a fold, or mantle, supporting the outer shelly skeleton. The jaws consist of two pairs of maxillæ, and a pair of mandibles, and the lower part of the head is inferiorly continued into the stalk, which contains the gland secreting the cement. If a barnacle be carefully removed from its point of attachment, the remains of the first pair of antennæ may be observed on the adhesive surface. When first hatched, the young are in the Nauplius stage, being furnished with a median eye, and three pairs of appendages, of which the posterior two are branched. After swimming for a while by means of these appendages,



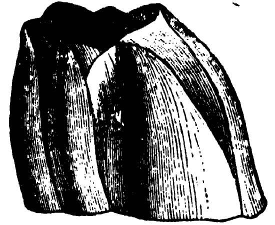
BARNACLES ATTACHED TO PUMICE.

the larva moults several times, and passes into a second stage, in which, with its two eyes and compressed carapace, it resembles a *Daphnia*. The rudiments of the six pairs of thoracic legs appear behind the mouth, and the first pair of swimming appendages become antenniform, each being provided with a sucker. By means of these suckers the larva fixes itself to its permanent resting-place, and, the cement-gland pouring out its secretion, glues the creature firmly to its point of attachment. Hence it follows that the fixed end of the stalk is the front extremity of the body. In the allied stalkless barnacle (*Megalasma*) the shell is attached directly to the support. We are thus led on to the acorn-barnacles (*Balanus*), in which the entire animal is enclosed in a shell formed originally of six pieces, which grow into a tube of variable length. Some of the latter group (*Balanidæ*), namely, the genus

Coronula, or coronet-barnacles, attach themselves to the skin of whales. The burrowing-barnacle (*Tubicinella*) has the same instinct. When adult it is long and cylindrical, consisting of a stout, stony rod, marked with a series of annular ridges. This is buried deeply in the skin of whales, sometimes penetrating as far as the blubber.



STALKLESS BARNACLE (nat. size).

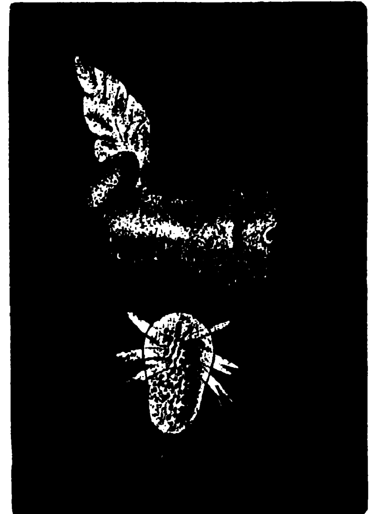


ACORN-BARNACLE (nat. size).

These Cirripedes are not true parasites, inasmuch as they do not extract nourishment from the animal to which they are attached; but many members of the group live exclusively upon other living beings, and nourish themselves at their expense. One form, for instance, *Proteolepas*, is in the adult condition a maggot-shaped, limbless, shell-less body, living within the mantle-chamber of other members of the same order; while the root-headed Cirripedes (*Rhizocephala*) live parasitically upon the higher crustaceans. They are degenerate forms, possessing neither appendages nor segments, the body being a mere sac, devoid of alimentary canal, and absorbing nutriment by means of the root-like processes branching throughout the body of the host.



PARASITIC CIRRIPEDE, *Sacculina* (nat. size).



PARASITIC BARNACLES.

Upper Figure—*Peltogaster curvatus* (enlarged 1½ times); Lower Figure—*Nauplius* larva of *Parthenopea* (enlarged 200 times).

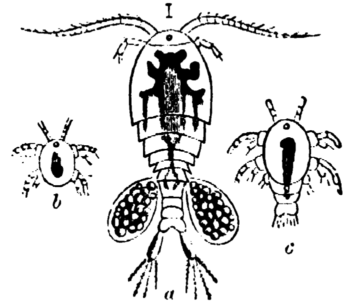
BIVALVED GROUP,—Order OSTRACODA.

This order is a small assemblage, characterised by the possession of a bivalved shell, formed from the right and left halves of the carapace, and furnished with an elastic hinge to separate the valves and a muscle to keep them shut. The shell encloses the body which is unsegmented, has a rudimentary abdomen, and bears seven pairs of appendages, namely, two pairs of antennæ, three pairs of jaws each belonging to the head, and two of limbs attached to the thorax. These limbs, however, are stout and narrow, and, as a rule, there are no special respiratory

organs. Ostracods occur both in fresh water and the sea; the best known forms being *Cypris* and *Cythere*. The former contains species found in ditches and ponds in England. When the waters in which they live dry up, the species of *Cypris* bury themselves in the mud until rain falls; the eggs, which are spherical, being attached to aquatic plants. The species of *Cythere* are mostly marine, haunting rocky pools on the coast, and crawling amongst the seaweed. In *Cypridina*, on the contrary, which is also marine, the animals dart about with velocity; the females carrying their eggs between the valves of the shell attached to their feet.

OAR-FOOTED GROUP,—Order COPEPODA.

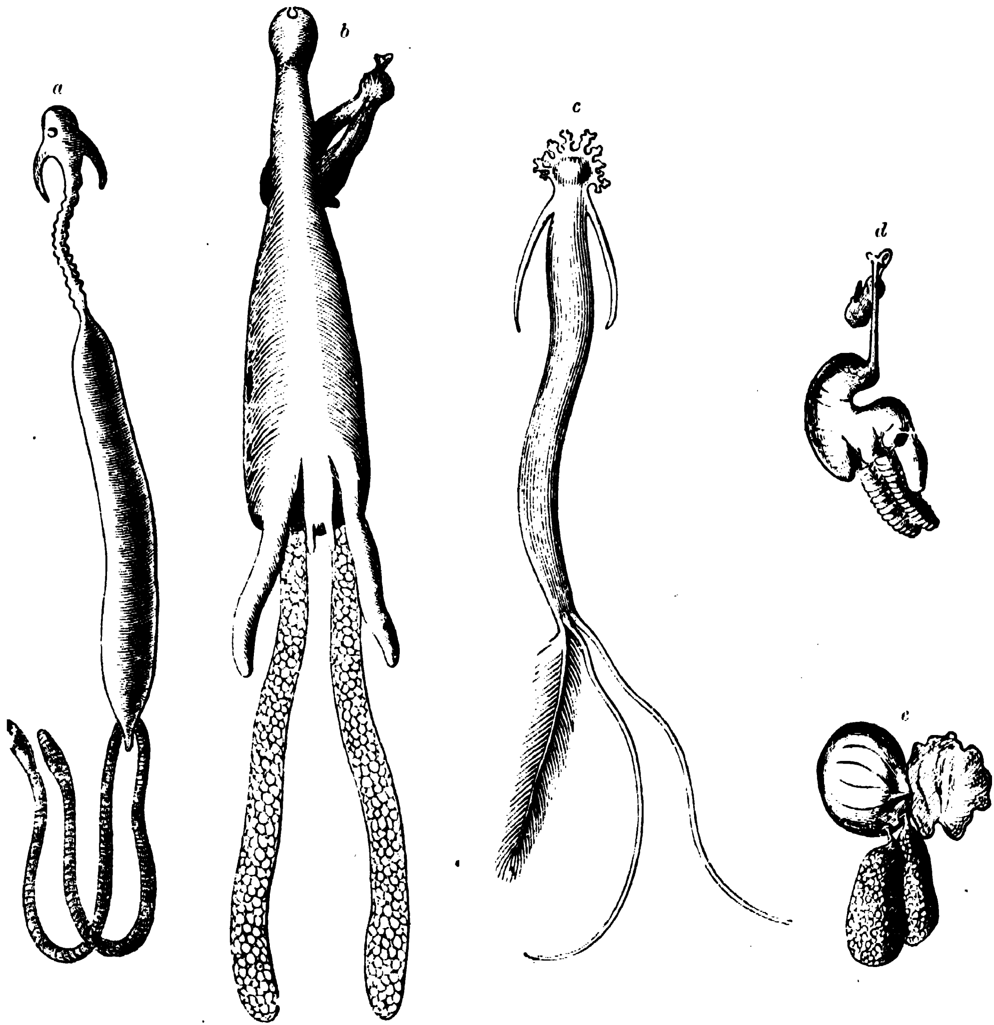
In the free-living members of this group, the body is elongate and segmented; the thorax bears four or five two-branched swimming-feet, and the abdomen is without appendages. A common fresh-water form is *Cyclops*, the structure of which serves as a type of that of the order. The body is broad in front and tapering behind, being thus pear-shaped in outline. The normal five pairs of head-appendages are well developed, the first pair of antennæ being long and acting as oars. The dorsal elements of the head are fused to form a carapace, which bears a single eye in front and is behind united to the first thoracic segment, the remaining five of this region being free. The abdomen consists of four narrow cylindrical limbless segments; but the last bears a pair of processes severally tipped with a tuft of four long bristles. The eggs are carried by the mother in a couple of oval sacs attached to the last segment of the thorax, and so prolific are these creatures, that a female, it has been calculated, will in a year produce over four thousand million young. The young when hatched is an oval *Nauplius* (*b*), which gradually acquires the characters of the adult. Closely resembling the preceding is the marine *Cetochilus*, which is devoured in large quantities by whale-bone whales. These crustaceans are of a bright red colour, and when seen in myriads give the sea the appearance of being stained with blood.



COPEPODS.
a, Female *Cyclops*, with egg-sacs; *b*, *c*, *Nauplius* and later larva of same.

The Copepods hitherto noticed are spoken of as the Eucopepoda, but we now come to a number of genera which have taken to a parasitic life, these Epizoa, or Parasitica, being strangely unlike the higher forms. As one of the least modified types, may be mentioned the carp-louse (*Argulus*). Of the more degenerate types, the structure is exemplified in the annexed cut. In these the body may be broad and flat, as *Caligus* (*e*), which is frequently found upon the cod-fish and the brill, or long and worm-like, as in *Lernæonema* and *Pennella* (*a* and *c*), the former being a common parasite on the herring and sprat, while in *Lernæa*, the gill-sucker, to which *Hæmobaphes* (*d*) is allied, the body is swollen and twisted in the form of the letter S. The two long processes represented in the figures projecting from the posterior end of the body are the egg-sacs. The appendages

of the head and thorax are more or less reduced, being either absent or converted into adhesive hoops or suckers.



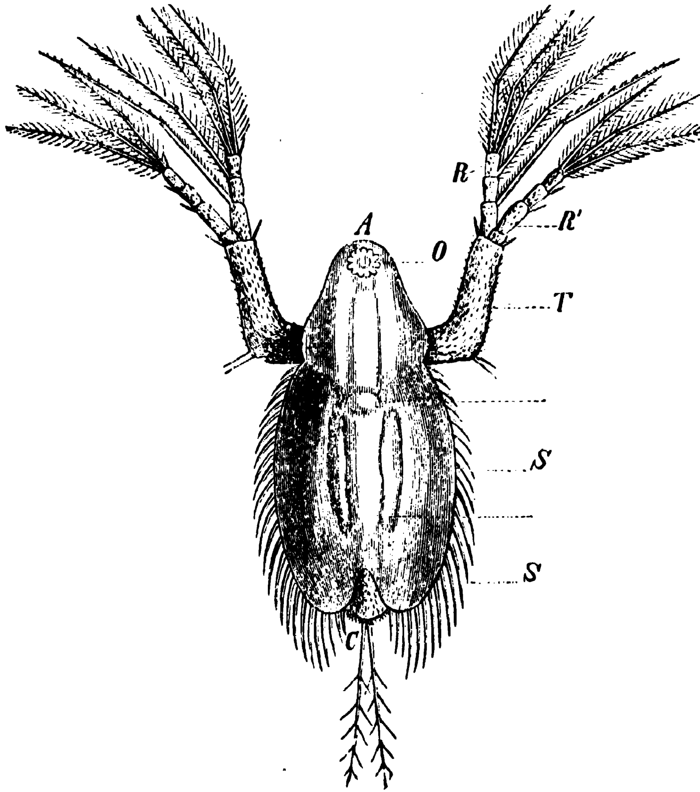
FISH-LICE.

a, *Lernæonema* (enlarged 3 times); *b*, *Brachiella* (enlarged 9 times); *c*, *Pennella* (enlarged 5 times); *d*, *Hæmobaphes* (nat. size); *e*, *Caligus* (enlarged 3 times).

Order Cladocera.

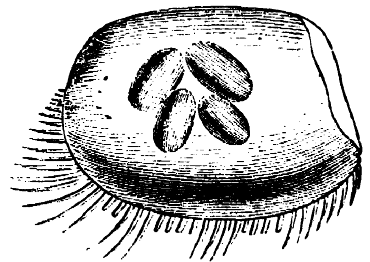
The members of this order take their names from the large and branched antennæ, which serve as swimming organs. They are all small, and the carapace forms a bivalve shell enclosing the greater part of the body, this carapace being an extension of the dorsal surface of the head-segments. An example of the order is the water-flea (*Daphnia pulex*), to which *Acanthocercus*, represented in the figure on p. 285, is nearly allied. Here the body is narrowed in front, and at the posterior end, where the carapace (S) is deeply notched, is the tip of the abdomen (C), bearing the pair of rigid barbed setæ, from which the genus

takes its name. At the front of the head (A) is a large compound eye (O), and the branched and plumed appendages projecting from beneath the sides of



SPINY-TAILED WATER-FLEA, *Acanthocercus* (much enlarged).

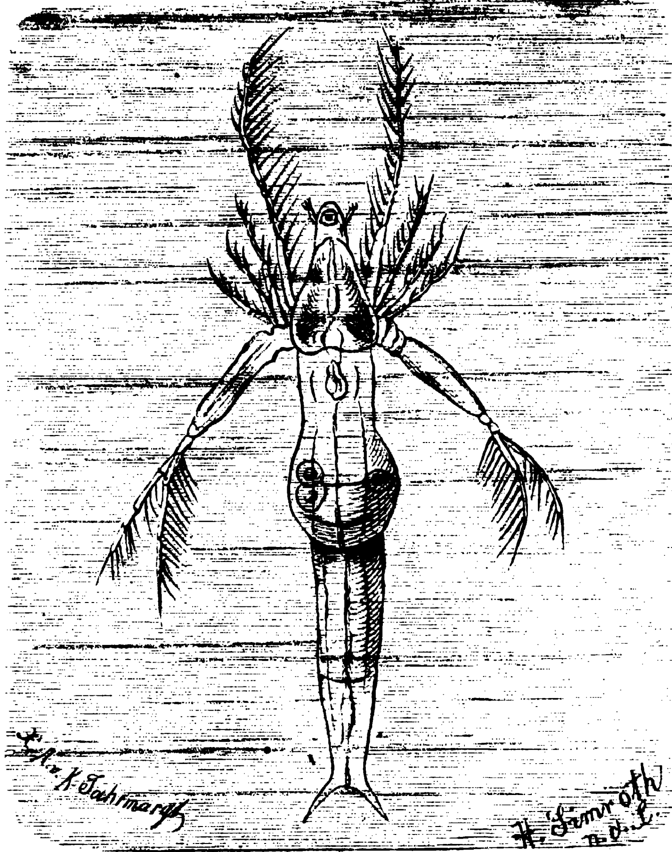
the head are antennæ (R, T). The first pair of antennæ are small and simple. The jaws consist of the mandibles and the first pair of maxillæ, the second pair of maxillæ being obsolete in the adult. The thorax comprises five segments, each bearing a pair of leaf-like swimming-limbs. The abdomen consists of three segments and is limbless. The males of *Acanthocercus* are smaller than the females and much rarer, being generally met with in the autumn. Eggs are laid both in summer and winter and are passed into a brood-pouch, separating the upper surface of the thorax from the backward extension of the carapace. Here the summer-eggs hatch, but the winter set are enclosed in a kind of capsule developed from part of the carapace. This capsule, called the *ephippium*, is cast off with the next moult of the mother's integument, and falling to the bottom of the water gives exit to the embryos, which hatch in its interior. Another type is the glassy *Leptodora hyalina*, so called on account of its semi-transparency, which inhabits the open water of fresh-water lakes. The shell is so much reduced as scarcely to envelop the animal.



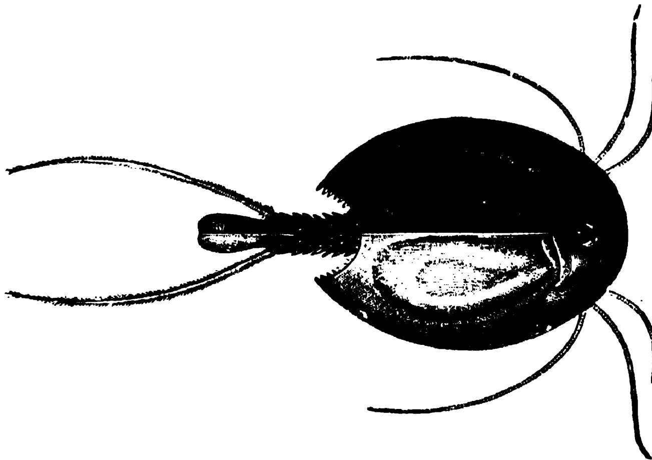
EGG-CAPSULE OR *Ephippium* OF WATER-FLEA, *Acanthocercus* (much enlarged).

Leaf-Footed Group,—Order Phyllopoda.

Some of the members of this group are relatively large, the body being long and composed of a great number of segments, of which the thoracic, and sometimes the abdominal, are furnished with leaf-like gill-bearing appendages.



THE GLASSY LEPTODORA, *Leptodora hyalina* (enlarged 12 times).



SCALE-TAILED APUS, *Lepidurus* (nat. size).

In the family *Apodidæ*, containing the genera *Apus* and *Lepidurus*, the anterior end of the body is covered with a carapace, projecting from the head over the free segments of the thorax. The hinder border of this carapace is deeply cut out, and near its front end there is a pair of contiguous compound eyes. The mouth is bounded in front by a large upper lip and behind by a deeply cleft *metastoma*, or lower lip. Both pairs of antennæ are short. The jaws consist of a pair of mandibles and two pairs of maxillæ; these are followed by eleven pairs of thoracic limbs, and there are appendages on the abdomen, sometimes numbering as many as fifty-two pairs. The last segment of the abdomen bears a pair of long filaments, and sometimes, as in *Lepidurus*, a distinct caudal plate. These crustaceans occur in the fresh waters of most countries. They swim on their backs, using the legs as paddles; and the eggs are capable of surviving long periods of drought when embedded in dried mud. In the second family—the *Branchipodidæ*—the body is also elongate, but there are no appendages to the abdomen, which consists of nine segments, while there are eleven pairs of thoracic appendages. The head-shield is not developed backwards, and the large separated eyes are supported upon distinct stalks. In the male, the second antennæ are converted into claspers. These forms likewise swim upside down. Some (*Branchipus*) occur in fresh waters, but others (*Artemia*) prefer briny pools and flourish in water so strongly charged with salt as to be fatal to other crustaceans.



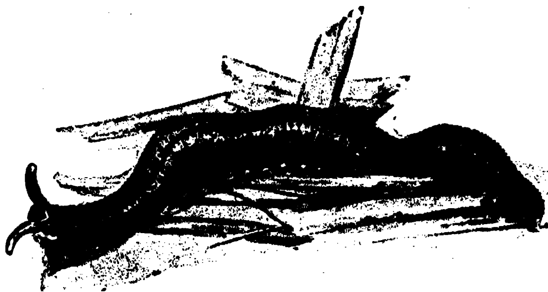
a, MALE OF *Branchipus grubei* (nat. size); *b*, FEMALE OF *Branchipus grubei* (nat. size); *c*, MALE OF BRINE SHRIMP, *Artemia salina* (enlarged).

Class **Prototracheata.**

This term is applied to the group now claiming attention, because in many respects it occupies a place between the Tracheates and Worms, and is consequently regarded as allied to the ancestral form from which all Tracheates have been evolved. Unlike the true Arthropods, the limbs are not jointed; and the tough integument is covered with bristle-bearing papillæ, but is not divisible into segments. The long body is shaped like that of a caterpillar or slug, and to the sides of its lower surface are attached a number of short more or less conical legs, each tipped with a pair of strong claws. The head is supplied with a pair of stout longish antennæ, at the base of each of which, on the outer side, is an eye. On the lower surface of the head is placed the mouth, supplied with fleshy lips and two pairs of toothed horny jaws; and on each side of the head there is a modified appendage known as the oral papilla. The chief features to note in the internal organisation are the presence of segmentally arranged kidneys— one opening at the base of each leg—and the wide separation of the two strands of the ventral nerve-chord. This last character is found in some of the lower worms, and the numbers

of paired kidneys in the higher members of the latter group. The class contains only the single family *Peripatidæ*, which has a wide but somewhat singular distribution. The genus *Peripatus*, for example, is spread over the West Indian Islands, ranging from Nicaragua through the northern parts of South America to Chili, and has also a single representative in Sumatra; while *Peripatopsis* is confined to Cape Colony, and *Peripatoides* to Australia and New Zealand. These three genera are easily distinguishable by external characters, and differ both in internal features, and also in embryonic development. Nevertheless, all the species seem to be closely similar in habits, living beneath the bark of trees, in the crevices of rotten stumps, and under decaying leaves, but always in damp localities, being exceedingly susceptible to drought. Locomotion is slow, and effected entirely by the legs, the body being kept rigid; and in walking every inch of the track is carefully explored by the antennæ, which are so sensitive that they seem able to learn the nature of an object without actual contact. The sole function of the eyes seems to be to distinguish light from darkness, though it is possible that being nocturnal the animal may be able to see to a slight extent in a subdued light. When irritated, these creatures spurt from their oral papillæ a quantity of slime at the offending object, and with the same sticky substance entangle their prey, which consists of small insects. A specimen of *Peripatopsis capensis* has been seen to overcome a small scorpion by this means. This slime—secreted by two long glands extending from the oral papillæ far back into the body—can be ejected to a distance of about a foot. Curiously enough it will not adhere to the skin of the *Peripatus* itself. In one of the Australian species (*Peripatoides oviparus*) the mother lays her eggs in damp spots; but, as a rule, the young are born alive, and although the mother takes no special notice of them they crawl upon her back for protection.

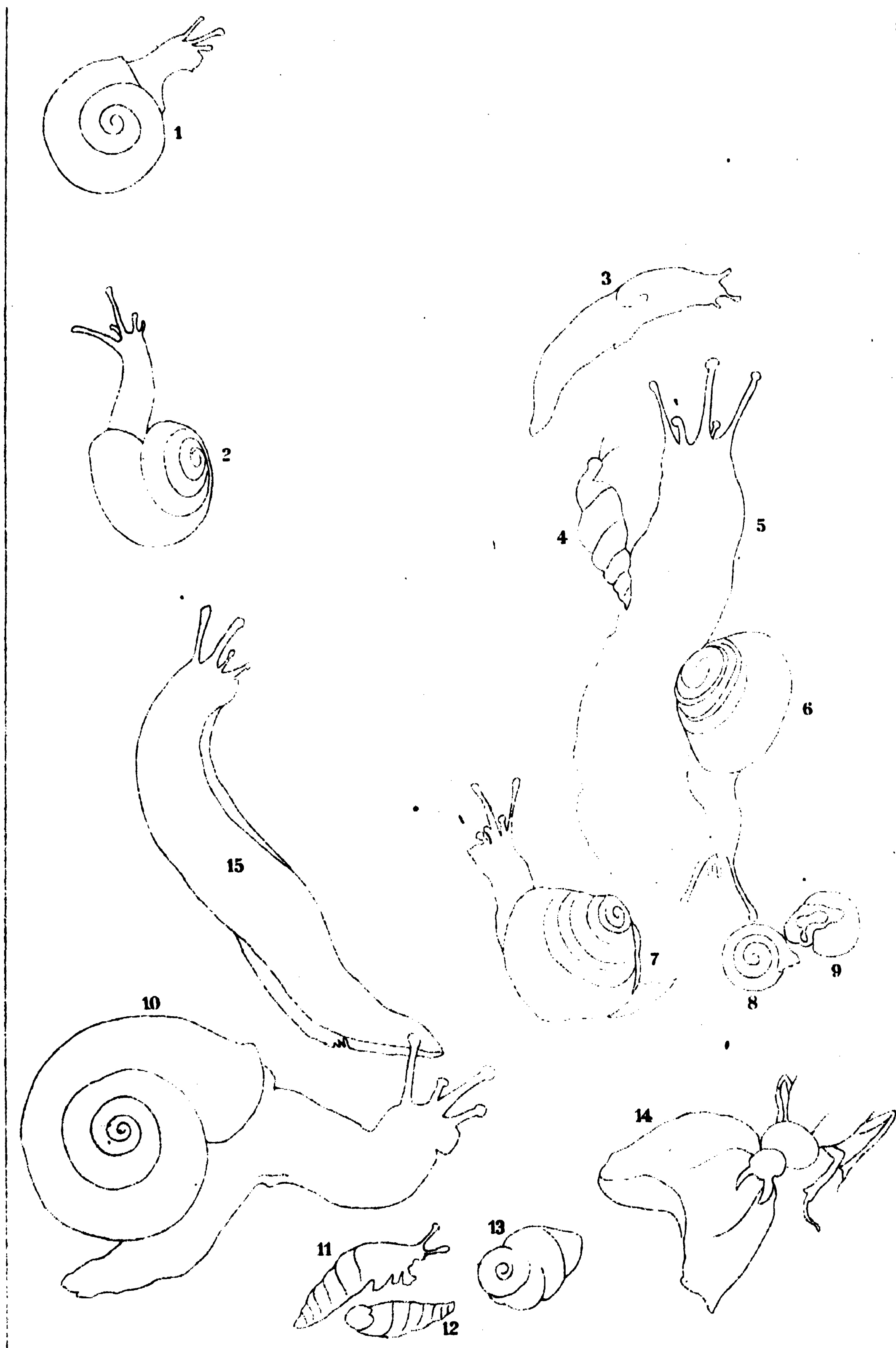
R. I. POCOCK.



Peripatus edwardsii (nat. size, from life).



LAND MOLLUSCS.



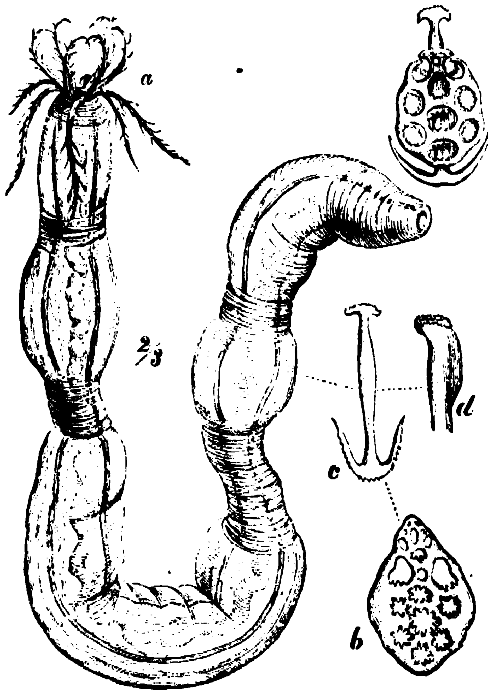
1, 2. Varieties of *Helix hortensis*.
3. *Agriolimax agrestis*.
4. *Buliminus montanus*.
5. *Limax maximus*.
6, 7. *Helix nemoralis*.
8, 9. *Helix personata*.
10. *Helix pomatia*.
11, 12. *Clausilia ventricosa*.
13. *Cyclostoma elegans*.
14, 15. Varieties of *Arion empiricorum*.

CHAPTER VIII.

STONE-LILIES, STAR-FISHES, SEA-URCHINS, AND SEA-CUCUMBERS, Subkingdom **ECHINODERMATA.**

Characteristics of the Group. THE star-fish, the sea-urchin, the brittle-star, the feather-star, and the sea-cucumber—especially the three former—are well known to all frequenters of the seashore; while the fossil sea-urchins of the Chalk, whose flint-casts are so common on the downs of England, the so-called screw-stones found in the Mountain Limestone, the pentremites and crinoids, whose remains are so abundant in some parts of North America, are no less familiar to dwellers inland. Though these animals differ much from one another in shape, a slight scrutiny will discover many points in which they resemble one another and differ from other creatures. They and their relatives are, therefore, placed in one great group of the animal kingdom, the Echinodermata,—a group corresponding in importance to the Molluscs, or the Vertebrates. This group is, in fact, more clearly defined, and more widely removed from other groups than either of the two mentioned. If a star-fish, or any of the animals named above, even a sea-cucumber or holothurian, be touched with the finger, its skin will be found to have a rough surface; this is due to the circumstance that it contains a crystalline deposit of carbonate of lime. In a sea-urchin, a brittle-star, or a feather-star, this deposit is in the form of little plates, which build up a more or less rigid test; whereas in the star-fish it usually forms a kind of scaffolding, between which there stretches the more yielding, leathery skin. In the ordinary sea-cucumbers the deposit consists only of small spicules, which roughen the outer surface, and grate when the skin is cut with a knife. If a thin slice of the skin of one of these animals be cut and examined under a microscope, the spicules may easily be seen lying in its middle layer. It is this same deposit that forms the spines of a sea-urchin and the stalked column of a crinoid; and it is this which has enabled so many of the Echinodermata to be beautifully preserved as fossils. To this character is due the name of the group, derived from the Greek, *echinos*, a hedgehog, and *derma*, skin. Many animals have some deposit of lime, such as the shells of the Molluscs, and the bones and teeth of the Vertebrates, but the deposit of the Echinodermata differs in two characters: first, that its microscopic structure is that of a meshwork, or rather of a beam-and-rafter work, since it is deposited in the spaces of a network of soft tissue; secondly, that each element, whether a spicule or a plate, is, despite its trellised structure, deposited around regular lines of crystallisation. Owing to these characters, the minutest portions of an echinoderm skeleton can be recognised, even when fossilised. This tendency of the Echinoderms to deposit lime is not confined to the skin, the walls of the

internal organs being often strengthened by a deposit of similar structure. Although, as has been said, each element of the skeleton follows the laws of the typical crystallisation of carbonate of lime, yet the structure of the trellis-work varies greatly, and is often characteristic of the species in which it occurs. Thus, the species of sea-cucumber can be distinguished by the shape of their spicules; and the same is said to be the case with those sea-urchins that deposit spicules among their viscera.



ANCHOR SEA-CUCUMBER (*Synapta*).

a, Tentacles round the mouth ; *e*, Anchor- and plate-shaped spicules ; *b*, *c*, *d*, Similar spicules of an allied form.

The next feature noticeable is the radiate structure, in many cases giving to the animal a star-shape, to which the common names star-fish, brittle-star, and the like are due. The ordinary red star-fish, or cross-fish, of the English coasts has five distinct rays, or arms; and this number five, to a greater or less extent, controls the arrangement of the organs in the majority of the Echinoderms. It can be detected even in a sea-cucumber or holothurian, where, beside the feathery tentacles of the head, are rows of shorter sucker-like processes, which extend the length of the body; these rows being five in number. The internal organs, as will be seen later on, are variously affected in the various classes of the Echinoderms by this five-rayed symmetry. A radiate arrangement is not, however, confined to Echinoderms, as it also occurs in jelly-fish and sea-anemones. Hence those animals were once grouped with the Echinoderms, under the title of Radiata. But, if a sea-cucumber or a sea-urchin be opened, there is a marked distinction between it and a jelly-fish, in the presence of an intestine, shut off from the rest of the body-cavity, and often coiling round inside it. In this respect the Echinoderms resemble all the animals that have been dealt with in the preceding pages, whereas the jelly-fish and their allies differ from them in having no body-cavity separated off from the stomach and its processes. Moreover, Echinoderms resemble the higher animals in the possession of a system of branched tubes conveying blood through the body.

Examining a star-fish or a sea-urchin, one sees, on the under surface of the rays in the former, and passing in five bands from top to bottom of the latter, a number of small cylindrical processes, which are usually gently waving about like trees in a wind. They lie in each band, or in each ray, along two rows, with a clear space between, like trees on either side of an avenue; hence the whole band of them in each ray is called an ambulacrum (garden-walk). Most of these little processes end in sucker-like discs, which the animal can stretch out and attach to smooth

surrounding objects; and it is thereby able either to hold itself firm against waves or currents, or to pull itself along. Hence these processes are usually called



SEA-CUCUMBERS AND A BRITTLE-STAR.

tube-feet; but sometimes they end in a point, and cannot assist in locomotion, though they may help respiration, when they are sometimes called tentacles. If a single foot be touched, it immediately shrinks up, and if the touch be vigorous, the adjacent tube-feet probably follow its example. Tube-feet torn from the animal sometimes continue their waving motion, showing that this is, partly at least, due to muscular action. Their movements are also caused by the squeezing of a fluid into them; for each foot is like an indiarubber tube closed at the end, and passing through the test (as the shell of the sea-urchin is termed) to join with one main tube, which runs along under the ambulacrum in a radial direction; and before it joins this radial canal, each tube-foot gives off a small swelling likewise filled with fluid, so that when this swelling is contracted all the fluid is squeezed up into the foot, and pushes it out like the finger of a glove when blown into. The radial canals pass along under the ambulacra till they join in a ring-canal surrounding the mouth. Eventually this circular canal is connected with the surrounding water by a canal passing right across the body-cavity to the other side of the animal, near the vent, where it opens to the exterior through a plate pierced with a number of pores. This plate is called the madreporite, and the canal leading to it—owing to the limy deposits formed in its walls—the stone-canal. This whole system of fluid-filled canals is termed the water-vascular system. The foregoing description refers to its arrangement in a star-fish, or regular sea-urchin; but the system occurs, with various modifications, in all Echinoderms, and is one of the features that separate the group from other animals.

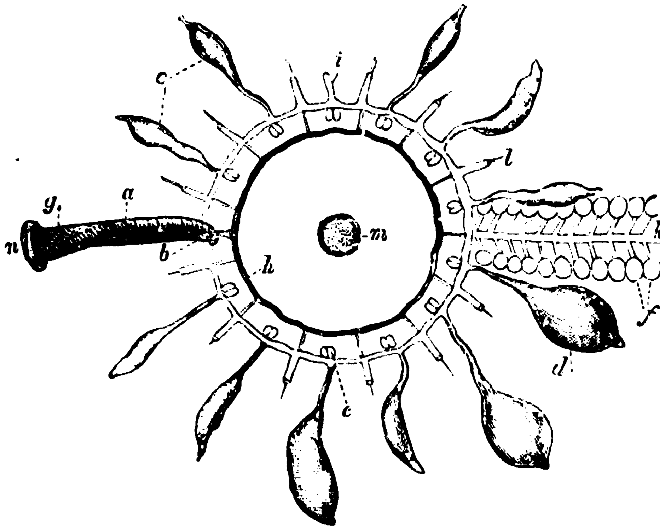


DIAGRAM OF AMBULACRAL SYSTEM OF A STARFISH.

f, Small swellings connected with the tube-feet; *k*, The radial canal with which they unite; *e*, Ring-canal into which the radial canals open; *c*, *d*, Membranous sacs that serve as reservoirs for water from radial canals; *a*, Stone-canal, leading from ring-canal to the madreporite, *n*; *m*, Mouth.

The Echinoderms are also peculiar in the possession of three, or perhaps four, different systems of nerves, of which three, or at least two, are present at the same time. One system supplies the skin, the tube-feet, and the intestine; its chief parts being a ring round the mouth, and radial nerves radiating therefrom. The second system has a similar arrangement, but lies deeper, and supplies the internal muscles of the body-wall. The third system, which is most fully developed in crinoids, starts from the other side of the body, opposite to the mouth, and supplies the muscles that work the arms and stem. If the arm of a star-fish be opened from the back, there will be seen a pair of pleated extensions from the stomach. If these be removed, there will be exposed a pair of orange-coloured tubes, some-

what branched and knotty, which communicate with the exterior at the angles between the rays. These are the generative glands. In all Echinoderms, except sea-cucumbers, these glands are affected by the radiate structure of the animals; in crinoids the generative products are even produced in the extremities of the arms.

Distinction of the Classes. Having glanced at those points of structure in which Echinoderms resemble one another and differ from the rest of the animal kingdom, we may shortly examine the main characters in which a sea-urchin, a star-fish, a crinoid, a brittle-star, and a sea-cucumber differ from one another. First may be noted obvious differences in form and in position in the living state. In an ordinary sea-cucumber (as shown in the illustration on p. 291) the body is cucumber-shaped, with the mouth at one end and the vent at the other; between these run the five ambulacra, one or two of which are often more developed than the others, so that the animal crawls along on that side of its body, with its mouth foremost. A sea-cucumber has no arms or projecting rays, but its mouth is surrounded by a circlet of tentacles, often branched, which can be retracted at will. A regular sea-urchin, such as the sea-egg (*Echinus*), shown in a later figure, resembles a sea-cucumber in being without projecting rays; but it is more spherical in shape, and moves with its mouth towards the sea-floor. On the other hand, in a heart-urchin (*Spatangus*), which moves through and swallows mud and sand, the body has become transversely elongate; that is to say, the long axis is at right angles to the position it occupies in a sea-cucumber; the mouth having moved a little forward, and the vent being transferred from the top of the body to its lower surface, so that both the mouth and vent lie on the under surface, at either end of the long axis. In a star-fish, as in a regular sea-urchin, the mouth is in the centre of the under surface, while the vent is almost in the centre of the upper surface, although absent in a few forms. The body is either markedly pentagonal in outline, or more or less star-shaped. In the latter case it is said to consist of a central disc extended into arms, as in the illustration on p. 304. The number of these arms varies from five (*Asterias*) to over forty (*Heliaster*); but in each species with more than six arms the number may vary slightly, although constant during the life of the individual; in *Labidiaster*, however, fresh arms grow out even in the adult. A brittle-star (illustrated on p. 291) resembles a star-fish in which there is a sharp distinction between arms and disc; the mouth being on the under surface, but the vent wanting. And whereas the arms of a star-fish are simply extensions of the body, containing the generative glands and processes from the stomach, those of a brittle-star are mere appendages to the body, with a stout internal skeleton of separate ossicles, working on one another by well-developed muscles, and containing only blood-vessels, water-vessels, and nerves. The arms of the brittle-stars are nearly always five in number, though sometimes there may be from six to eight. As in the star-fish, the arms are unbranched, except in the family *Astrophytidæ*, where they fork ten or twelve times, and where the numerous branches interlace so as to form a kind of basket-work all round the disc, whence these animals are called basket-fish, or medusa-head star-fish. A crinoid (illustrated on p. 297) differs markedly from a sea-urchin, star-fish, or brittle-star, in that the mouth faces upwards; the vent being also on the upper surface. This position is due to the fact that, so far as we know, all crinoids are

at some time of their lives attached by a stalk to the sea-floor, or some other object, so that the mouth and vent naturally move up to that side of the body furthest from the stalk. This fixed state of existence has also caused the development of arms, five in number, but often forked many times, which arms stretch out from the body on all sides of the mouth, and contain extensions of the nervous, blood-vascular, water-vascular, and generative systems. The representatives of the tube-feet are arranged along the sides of these arms, on their upper or oral surface, and between them is a groove, which is lined at the bottom with cilia, or extremely minute hair-like processes, that keep waving in the direction of the mouth, and so



GROUP OF STONE-LILIES (PENTACRINIDS).

maintain a constant stream of water towards the latter; such water containing the minute animalculæ and fragments of decaying organic matter on which the crinoid feeds. The extinct cystids and blastoids have their mouth in a similar position to that of the crinoids, and for a similar reason, but have not similarly branched arms. In the blastoids five grooves radiate down the body from the central mouth, and from the sides of these grooves there spring small, jointed, but unbranched processes, called pinnules. The stem of the blastoids is very short, so that when the pinnules have been lost, as is usually the case, the five-grooved body looks like a bud, whence the name of the class. It is difficult to describe a cystid as having any definite shape, for the various animals to which this name is applied differ greatly from one another in structure. Echinoderms are built upon

one or other of the plans of structure just described. Moreover, the animals formed upon any one of these plans are found to agree with one another and to differ from the rest in yet other features. Hence zoologists have divided the Echinoderms into seven classes, each of which is again divided into orders.

Mode of Life. All Echinoderms live in the sea, where they find in solution the lime-salts from which their skeletons are built. None have become modified for a truly fresh-water existence, and in this respect they are peculiar among animals; a few holothurians, however, are found in the mud of some estuaries and brackish-water lagoons, while a star-fish (*Asteracanthium*) and a brittle-star (*Ophioglypha*) occur in the brackish waters of the Eastern Baltic. Neither can Echinoderms live on land, and though they may exist for a short time out of the water when left by tides, still it is only in the water that they can breathe or feed. In the sea, however, they have a universal distribution; from ice-bound seas to the Equator; from shallow shore-pools to mid-ocean; from the surface to the abyss; on rocky shores, sandy beaches, muddy shoals, and bottom oozes, among the roots of the mangrove, or in the meadows of seaweed. This universal distribution renders their study one of importance for the geologist, especially as their calcareous skeletons are readily preserved as fossils. Their remains are known from rocks of every age in which animals are known to have existed, and even the spicules of sea-cucumbers have been found as far back as the Carboniferous period. Moreover, the rapidity of evolution in the group, and the short period of time during which any one species was in existence, combined with the wide area of distribution possessed by many species, render these fossils of great value for the correlation of strata in different countries.

THE CYSTIDS,—Class **Cystidea.**

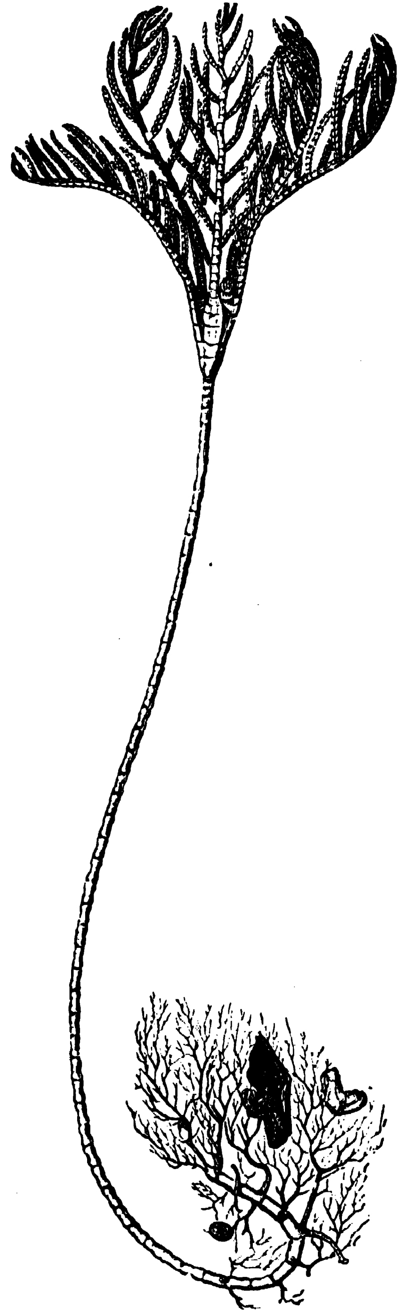
The Cystidea have been extinct since the Carboniferous period. Not only are they among the oldest animals, but there is reason to suppose that they approach more nearly the primitive forms from which all the classes of the Echinoderms were derived. Many have not that regularity of symmetry which characterises later Echinoderms. Such forms as *Echinosphæra,* commonly called the crystal-apple, are mere round balls composed of a number of plates in which it is hard to see any arrangement. Some of them seem to have been unstalked, while in others the stalk is quite short. The arms are short, and vary in number, bearing but slight relation to the plates of the test. In some, however, such as *Glyptosphæra*, the ambulacral grooves, though rather irregular, are five in number and lie on the surface of the test, all meeting at the mouth, which is placed in the centre of the upper surface. Other cystids seem to be composed of an irregular number of plates; but they have become more definitely radiate in structure. Some, like *Agelecrinus*, are flat circular forms, which live attached by their under side to the flat surfaces of shells, and which have five distinct ambulacral grooves radiating from the central mouth on the upper side; while others, like *Mesites,*—which resembles *Agelecrinus* in the arrangement of its grooves,—were attached, if at all, by only a small part of the under side. Yet other cystids are definitely attached by well-developed stalks, and have their bodies enclosed by a limited

number of plates arranged in regular order. Some of these present a six-rayed symmetry, such as *Caryocrinus*, while others are governed by a five-rayed symmetry, such as *Lepadocrinus* and *Porocrinus*. Both of these groups have as a rule better developed arms, which sometimes branch, and are usually five or six in number according to the symmetry of the cup. Hence these forms are much more like the crinoids than are the other cystids.

In other Echinoderms the rays with their numerous tube-feet help the respiration of the animal, but these were absent or very slightly developed in the cystids. There are, however, other structures that are supposed to have served the same purpose. In some (*Aristocystis*) the plates of the test are pierced by simple pores, while in others (*Glyptosphæra*) these pores are in pairs; but in either case the pores are scattered irregularly over the body, and possibly gave passage to minute tube-feet. The development of these and their concentration in certain areas of the test would produce an arrangement not unlike that of other Echinoderms. Other cystids have certain portions of the test pierced by slits (*Lepadocrinus*), and it seems probable that these permitted the surrounding water to pass in to the membrane, lining the interior of the test. These structures are called hydrospires (water-breathers), and somewhat resemble the cribriform organs found in some deep-sea star-fish of the present day (*Porcellanaster*), figured later on. Structures called hydrospires have also been described in such cystids as *Caryocrinus* and *Echinosphæra*; but it is doubtful whether these actually subserved respiration, although the true hydrospires may have been evolved from some such undeveloped structures.

Another point of interest in the cystids is the light they throw on the origin of the crinoid stem, which is formed of a series of flat rings. The simple round plates, with a circular hole through the middle, are often called St. Cuthbert's beads, while those marked with five petals, so common in the Lias at Lyme Regis, have been termed star-stones. Technically the two kinds are distinguished as Entrochi and Astroites. They are familiar in the polished slabs of Mountain Limestone, in which it may be seen how the long stem is formed of a number of these round ossicles jointed together, and pierced throughout by a narrow canal. The ossicles are joined by ligaments passing right through their solid substance, and endued with slight muscular power; the central or axial canal serving for the passage of blood-vessels, which are surrounded by a sheath of nervous tissue that controls the movements of the stem. By one end the stem is attached to the sea-floor, either by a flattish encrusting extension of its calcareous substance, or by a number of fine branches or rootlets, as in the root-crinoid (*Rhizocrinus*), herewith figured. By the other end the stem is attached to the plates forming the cup enclosing the body of the animal, and it is at this end that it grows, by the constant development of new ossicles between the cup and the upper segments of the stem. Now, if we suppose that the crinoids, like other Echinoderms, sprang from sac-like ancestors with a number of irregular and small plates, it is difficult to understand how such a stem was evolved; but the mystery is elucidated by some of the cystids and older crinoids. First, it may be noted, that in those cystids possessing a crinoid-like stem, as well as in many of the older crinoids, the axial canal of the stem is much larger than it is in later forms. Secondly, that in many

older crinoids, the ossicles of the stem, instead of being simple rings, are generally composed of five equal parts. In other words, there are five radial sutures or joint-surfaces, running the whole length of the stem and dividing each ossicle into five parts. These sutures are more conspicuous towards the root end of the stem, which was of course the first to be formed in each individual. Thirdly, examination has shown that in some of these stems, especially towards the root end, the five portions of each ossicle do not lie regularly above the five portions of the underlying ossicle, but alternate with them to a certain extent, just in the same way as the circlets of plates that make up the cup of a crinoid alternate with one another. These facts alone would lead us to suppose that the stem was originally composed, like the cup still is, of a series of circlets of small plates, five in each circlet, and alternating with one another; that the stem was, in fact, nothing more than a continuation of the cup, with essentially similar structure. Turning to the cystids, we may see how this view is confirmed and extended. In certain forms, such as *Trochocystis*, that part of the stem next the body consists of a double series of alternating plates, which are thin and enclose a large hollow. In *Arachnocystis* the whole stem consists of four or five series of alternating plates. In *Dendrocystis*, the plates forming the upper part of the stem can only be distinguished by their smaller size from those forming the cup; below they merge into the normal series of single ossicles. *Cigara* is the name given to a stem entirely composed of small irregular plates. We may, therefore, conclude that the stem originated as a portion of the body of the animal, elongated, and gradually becoming more and more regular in its structure. The curiously elongate and irregularly plated form called *Pilocystis* may represent the earliest stage in its evolution, before one can even say that a stem is differentiated at all.



LOFODEN ROOT-CRINOIDS (⅔ nat. size).

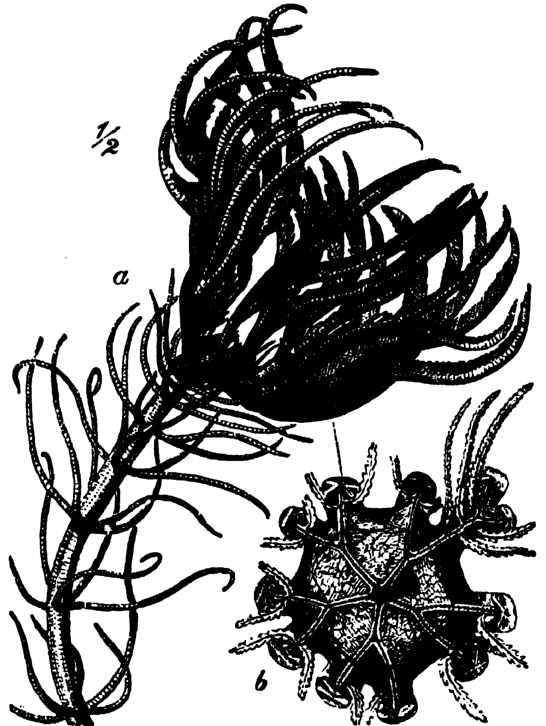
THE STONE-LILIES OR CRINOIDS,— Class **Crinoidea.**

The crinoids differ from the more highly developed of the cystids in the greater regularity of their structure—the symmetry of which is nearly always governed by the number five,—in the greater development

of the arms—which are often much branched,—and in the absence of special breathing-organs, which were no longer needed. It is easy to see how an organism that is fixed, and equally affected on all sides by the surrounding medium, whether air or water, develops a radiate symmetry; the same result being obvious in the case of most flowering plants. Slight consideration will also show why the number five has been favoured by these particular animals. The body of a crinoid is encased by a limited number of relatively large plates, united together by the skin in which they are developed, and it is clear that the sutures between these plates are lines of weakness. Supposing that there were four plates in each circle, then the four sutures would be in opposite pairs, and the lines of weakness would run right across the body of the animal, which would easily be broken; and the same result would follow if there were six plates and three pairs of opposed sutures. Though the test might be more flexible, still there would be three lines of weakness in each circle instead of two. But when there are five plates, each suture lies opposite to the middle of a plate, and so the line of weakness does not run right across the body. A few crinoids have essayed other forms of symmetry, but none have had a long existence. The alternation of the plates in a crinoid may be explained by similar mechanical considerations; for such an arrangement corresponds to the bonding of successive courses of bricks in a wall. There is reason to suppose that the ancestors of all crinoids, as well as most of the Palæozoic crinoids, were attached to the sea-floor or some other object throughout life by the stem. On hard rocky bottoms the attachment was by means of an incrustation, as in the pear-encrinite (*Apiocrinus*) of the Bradford Clay; but on oozy bottoms the end of the stem broke up into numerous branches called cirri, as in the *Rhizocrinus* of modern seas. In course of time these cirri were developed, not only at the root end, but also higher up the stem, and eventually they came in some genera to be arranged in regular whorls of five, as we see them in the living *Pentacrinus*. Since crinoids were at all times liable to be broken from their attachment, some of them gradually acquired slight faculties of locomotion, although they prefer to renew their attachment, even though this be transferred to some other object. Sometimes the whole end of the stem coiled itself around the stem of another crinoid, but usually it became anchored by such cirri as chanced to remain on the preserved portion. In those crinoids that have the cirri in whorls, the ligaments that unite the joints of the stem stop short just below each ossicle bearing a cirrus, so that the division between this ossicle and the one below yields readily to a bending or blow; and thus the crinoid can anchor itself easily by the whorl of cirri left at the end of its broken stem. In some cases there is developed at the end of the stem a little ball of calcareous tissue, serving as a weight to keep the animal right way up, as it moved slowly through the water by the waving of its arms; and in certain forms this ball developed spines, directed upwards like the flukes of an anchor, and serving the same purpose.

The stems of most crinoids have no great power of bending or coiling, since the ridges and ligaments are distributed equally all over the joint surfaces. Writing of pentacrinids, dredged in the Caribbean Sea, Professor Agassiz says: "They move the cirri more rapidly than the arms, and use them as hooks to catch hold of the neighbouring objects, and on account of their sharp extremities they

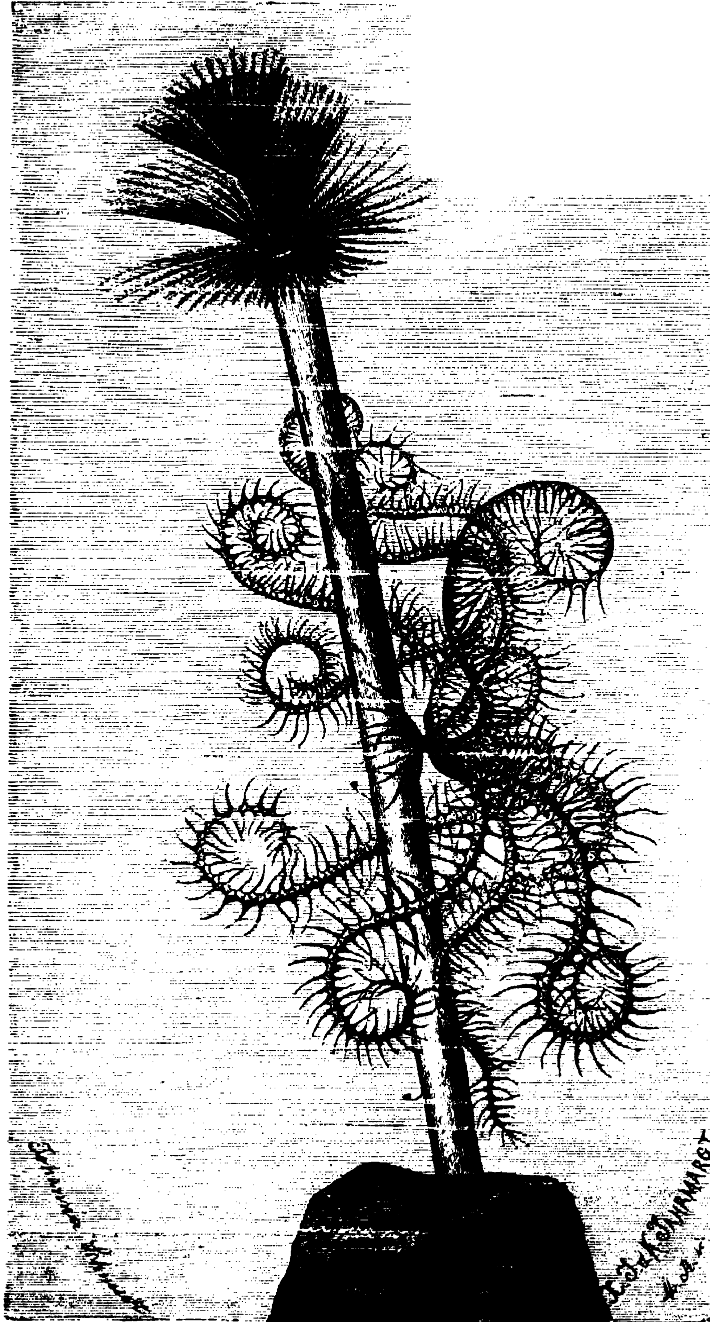
are well adapted to retain their hold. The stem itself passes slowly from a rigid vertical attitude to a curved or even drooping position." Other crinoids, like *Herpetocrinus*, have, however, a single fulcral ridge running across the surface of the joints, allowing far more play between the latter. In *Platycrinus* the joints had an elliptical outline, and the fulcral ridge formed the long diameter of the ellipse. Such a structure would naturally give the stem great power of bending, but only in one plane. This restriction was got over by giving the joints a slight skew, so that the stem was twisted like a corkscrew and capable of movement in every direction. In *Rhizocrinus* the same end is attained by each joint being so twisted that the fulcral ridge at the top is at right angles to the one at the bottom. These types are, however, merely side branches from the main stem of crinoid evolution; the chief advance having proceeded along the lines of free locomotion. At various periods forms have existed, which, having once tasted liberty, have gradually dropped all traces of their former attachment. Thus, *Agassizocrinus* of the Coal-Measures is a crinoid that has nothing left of its stem but a solid knob at the base of the cup; *Millericrinus* of the Great Oolite has been found at all ages and stages of development, the young individuals with a normal stem which gradually withers as the animal gets older, till in full-grown specimens it is a mere tapering process. *Uintacrinus* and *Marsupites* from Cretaceous beds, are two genera as unlike in essential structure as crinoids well could be, but resembling one another in having thin-plated large cups, without the smallest relic of a stem. A little crinoid of Jurassic age called *Thiollierierinus* appears, however, most nearly related to, if it be not the actual ancestor of, most of the free-moving unstalked living forms. It seems to have been related to *Bourgueticrinus* and *Rhizocrinus*, but, like *Millericrinus*, gradually dropped its stem, while the upper joint of the stem coalesced and began to bear cirri. In the common feather-star (*Antedon*) of the British seas this process has gone yet further; the animal breaks away from its stem when quite young, but retains the uppermost swollen and coalesced segments of the stem, which form one solid mass bearing a number of cirri, while the two lower circlets of cup-plates almost entirely disappear, so that only the upper circlet of plates, from which the arms arise, remains. The *Antedonidæ*, which have all arisen since Jurassic times, include not only numerous species of *Antedon*, but at



MEDUSA-HEAD PENTACRINID.

a, Crown and part of stem (nat. size); *b*, Upper surface of the body, the arms broken away, showing the food-grooves passing to the central mouth.

least as many more of a closely allied genus, *Actinometra*, as well as three other less common genera, named *Atelecrinus*, *Eudiocrinus*, and *Promachocrinus*. They are far more numerous at the present day than the stalked crinoids, and occur in all parts of the world, but their head-quarters are in the Eastern Archipelago.



ROSY FEATHER-STAR, CLINGING TO A TUBE OF SABELLA WORM (nat. size).

There are a few crinoids that have diminished their stem, but have nevertheless remained attached, so that at last the cup has come to be fixed on the sea-floor without the intervention of a stem. Such a form is the stumpy and thick-set *Holopus*, which is among the greatest rarities in museums. It lives at depths of about a hundred fathoms in the Caribbean Sea. Similar forms occur in some of the shallow-water and reef deposits of Jurassic and Cretaceous age. Many of these have become a little unsymmetrical and bent over in one direction; which may, perhaps, be accounted for by their life on reefs, where food is brought to them by currents flowing only in one direction.

Next to the stem, the most characteristic structures of a crinoid are its arms. Each arm starts from one of the five plates that form the uppermost circlet in the cup. The arms are said to be radial in position, and those plates from which they start are specially distinguished as the "radials." In many forms, such

as *Cyathocrinus*, the upper edge of each radial is notched by a horseshoe-shaped facet, provided with a transverse fulcral ridge and muscles, so that a regular articulation is formed for the working of the arm up and down. In such forms—known as Inadunata—the arms are quite separate from one another and are easily distinguished from the plates that compose the cup. But in the forms to which the names Flexibilia and Camerata are applied, smaller plates are developed in the spaces or interradii between the arms, and these additional plates bind the arms together and so incorporate them in the walls of the cup. A crinoid of this kind, such as *Actinocrinus* or *Uintacrinus*, has therefore a much larger body than a *Cyathocrinus* or *Pentacrinus*. Sometimes the arms form part of the cup without the intercalation of interbrachial plates; while yet other plates may be developed between the forks of the arms themselves. In the Flexibilia the plates that form the cup are rather loosely joined to one another, so that there is some play between them; the arms also have much power of motion. In the Camerata the plates are more firmly united, and additional fixity is given to the cup by the strengthening and solidification of the upper surface around the mouth. In the Inadunata and Flexibilia the grooves on the inner surface of the arms, which convey food to the mouth, pass over this upper surface of the cup, and are merely protected by the ordinary small plates that can be opened or shut down over them. But in the Camerata the plates of this upper surface of the cup have become so thick and welded together, that the grooves are no longer open, and even in some cases have been pressed down beneath the surface, underneath which they form regular tunnels. The mouth too is no longer visible on the upper surface. Crinoids of this type were most abundant in the Carboniferous period, and it is to a large extent their remains that make up the masses of Derbyshire marble.

Among curious modifications of arm-structure may be mentioned the Silurian *Crotalocrinus*. Here the arms are forked many times, but all the separate branches are joined together at their sides, so that the arms when outspread form a single net. In *Petalocrinus* of the same age this process has been carried so far that the branches of each arm are solidly fixed together, and the crinoid appears to be provided with five paddles. In *Uintacrinus* the ten arm-branches reached the enormous length of 3 feet, and seem to have been capable of movement in various directions, so that the swimming powers of the crinoid must have been greatly enhanced. *Saccocoma*, which lived in the still lagoons where the Solenhofen lithographic stone was deposited. had a very light body and long, fine arms, provided with flat oar-like processes.

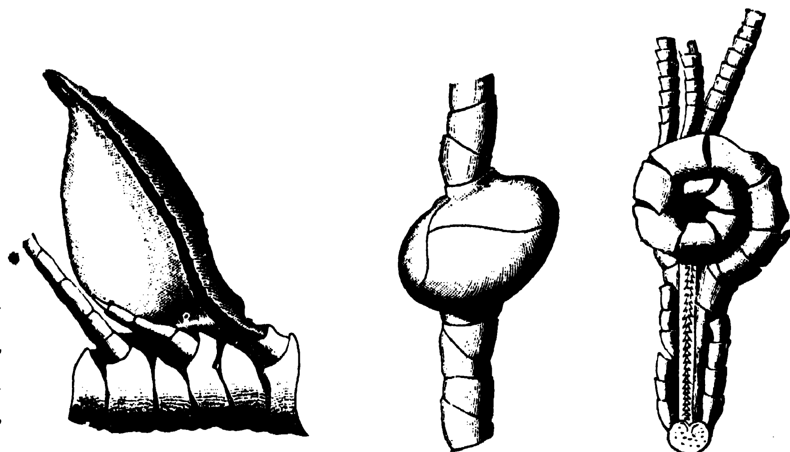
The locomotion of the free forms is effected by the raising and depressing of alternate arms, and the movements of these arms are correlated by the peculiar nervous system that has its headquarters at the bottom of the cup. This swimming has been observed in both *Antedon* and *Actinometra* kept in an aquarium. As a rule, however, these animals remain attached by their cirri to rocks, to the bottom ooze, to seaweeds, or to other marine animals. In this position the arms are outspread, and the small branches or pinnules that line their sides are kept slightly waving. If the water be ruffled, the first impulse of the crinoid is to flatten its arms out suddenly and to hold on to the rock or other object with its pinnules. The pinnules of an *Antedon* can be bent in any direc-

tion; those near the extremity of the arm being specially active. If its extremity be touched by any irritating substance, the arm is erected at right angles to the upper surface of the animal and so removed from the other arms, while the pinnules move something like the legs of a fly that is cleaning itself. If, however, this proves ineffectual, the arm bends over to the one on the opposite side, the pinnules of which then assist in the operation. The pinnules move in this manner to disembarrass the arm of fragments of foreign matter that are too large; but the hooks at the end of the pinnules can catch and retain minute fragments, which, as they decay, attract animalculæ, and so furnish food for the animal. If a stimulus be applied to any point on the under surface of the animal, the arms on the side from which it comes are simultaneously and forcibly pressed down, apparently to create a current that shall wash away the irritant. If an arm be cut off, it will continue to move for a short time. The crinoid, however, flattens its remaining arms, and rests immovable for half a minute; it then slowly crawls in a direction away from the wound. *Antedon* does not appear to like the light, and if placed on the surface of a stone in a glass vessel, always prefers to crawl to the under side, where it remains fixed by its cirri. If, however, a strong light be reflected on to the under side of the stone, while the top is kept dark, the animal will crawl back to the top. It is by crawling that the crinoid usually moves from place to place. The arms on the side towards which it intends to move, are stretched out; the pinnules are curved backwards towards the body, like so many grappling-hooks; and the arms are then curved up in S-fashion, thus dragging the animal along. Meanwhile, the arms of the opposite side move in the converse way, and their pinnules are directed away from the body, so that they push instead of pull.

At the present day crinoids live in all seas at depths between fifty and three thousand two hundred fathoms; but they prefer clear and undisturbed waters. The same has been the case in former geological periods, for while crinoids are abundant in limestones, of which their own remains form large masses, they are much rarer in sandstones and shales. As in the case of the well-known pear-encrinite, colonies of crinoids that lived in clear water have been suddenly overwhelmed by an influx of mud, which first killed and then preserved them. Unstalked as well as stalked crinoids live chiefly in colonies; but this is due less to sociability than to limited powers of motion even in the larval state. In the older rocks, individuals of many different genera and species may be found that lived in close association. In the later periods it is more usual to find numerous individuals of the same species in association; examples of such colonies among stalked crinoids are *Rhizocrinus* in the North Sea and off North America, *Bathycrinus* in the Southern Ocean, *Pentacrinus* off Portugal and in the Caribbean Sea, and *Extracrinus* in the Lias of Lyme-Regis.

The food of crinoids consists chiefly of foraminifera, diatoms, and the adults of small and the larvæ of larger crustaceans. Crinoids themselves form food for fish, though nowadays their place seems to be taken by the brittle-stars and an occasional sea-urchin. As protection against such attacks, some crinoids have been provided with spines, either as movable processes from the plates of the test, as in *Dorycrinus* from the Carboniferous of North America, or, very rarely, movably attached like the spines of a sea-urchin, as in *Hystricrinus* from the

Devonian of the same country. Parasites, however, find crinoids an easy and almost unresisting prey. A suctorial crustacean, eggs and all, has been found in the body-cavity, while a decapod crustacean occasionally inhabits the intestinal tube. The annexed figures represent the cysts formed by the crinoid in response to the irritation set up by the presence of a parasitic worm, in which cysts it takes up its abode. There are also worms that bore into the stem, as well as boring sponges, and corals that affix themselves to the stem. The crinoid generally makes some attempt to overwhelm these intruders by the rapid deposition of the calcareous skeletal substance; so that in the rocks greatly thickened stem-fragments are found enclosing the remains of corals, brachiopods, etc.



SWELLINGS IN THE PINNULES OF CRINOIDS PRODUCED BY A PARASITE (twice nat. size).

THE BLASTOIDS,—Class **Blastoidea.**

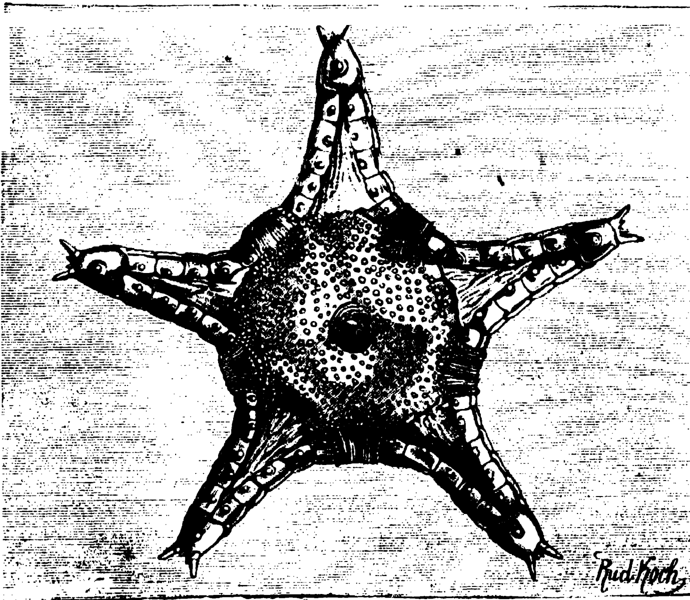
The Blastoidea constitute a compact group, pretty clearly marked off from both Cystidea and Crinoidea, which they resemble in the upward position of the mouth and the generally fixed habit. The chief character that separates blastoids from other echinoderms is the presence of an elongate plate, the lancet-plate, underlying the ambulacrum and pierced by a canal supposed to have contained the radial water-vessel. These five canals meet in a circular canal round the mouth, but there is no evidence that they were connected with tube-feet as in other echinoderms. Each side of each ambulacrum was lined by a row of delicate, unbranched arms; and the food-grooves of these arms passed to a single groove running down the middle of the surface of the ambulacrum, and these five grooves then passed up to the mouth.

The most interesting structures in the Blastoidea are the hydrospires. In such a form as *Pentremites* there are five openings (spiracles) round the mouth, placed in the interradial areas between the ambulacra. From each of these spiracles, a canal passes under the test in a direction away from the mouth. This canal soon branches, and a branch goes to the side of each ambulacrum. Each branch of the canal swells into a pouch with thin walls that are strengthened by a slight deposit of lime; and these walls are thrown into folds so that their surface is increased. There is thus a folded pouch running along the inside of the test under each side of an ambulacrum; and from this pouch short tubes are given off which open to the exterior through pores at the sides of the ambulacrum, which pores alternate

with the arms and are not in any way connected with them. These hydrospires are clearly quite different structures to either of the two kinds of structures that go by the same name in the Cystidea. They have been compared with certain structures in the Ophiuroidea. In the latter animals are oval pouches, which lie at the sides of the arms where they spring from the body or disc, and which open to the exterior by slits. Their walls are strengthened by calcareous rods, and into them the ovaries open, so that developing young are often found in them, as in the marsupium of a kangaroo. They are known as genital bursæ, but their folded inner walls probably serve to bring the outer aërated water closer to the internal organs of the body, that is to say, their function is in part respiratory. We may, therefore, fairly suppose that the hydrospires of Blastoids served primarily for respiration, possibly in place of tube-feet, and secondly for the maturation and transmission to the exterior of the generative products. All blastoids have not hydrospires of precisely the same structure as those above described, since in some they are more like the slits previously mentioned in *Lepadocrinus* and *Porocrinus*; while they are always in the same interradial position, which is not the case with the cystids.

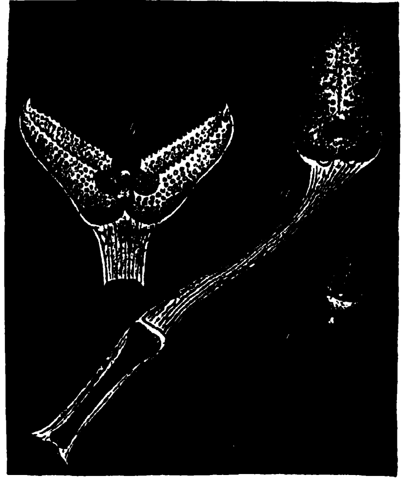
THE STAR-FISHES,—Class **Asteroidea.**

With the Asteroidea we come to echinoderms that differ from those hitherto described, and resemble those to be dealt with, in that none of them are fixed, but all are free-moving, and in the fact that the mouth is not directed upwards. There is, however, reason to believe that these free forms are, like the free crinoids, descended from ancestors that were fixed; and in the young *Asterina*, at all events, there is a prolongation of the forepart of the body, which not only corresponds in position to the prolongation that becomes the stem in crinoids, but actually serves for a short time as an organ of attachment. But whereas in the crinoid the mouth moves upwards to the surface opposed to this organ of attachment, and there becomes surrounded by arms, which similarly face upwards, in the asteroid the mouth and its surrounding arms are bent downwards so as to face the sea-floor, and the animal, instead of collecting its food from the water above, extracts it from the mud below. Correlated with this mode of life, the



BLUE CHINA STAR-FISH (nat. size).

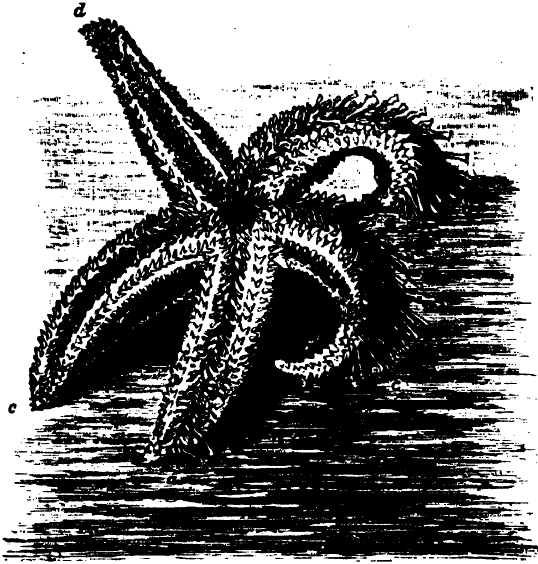
vent and madreporite are on the upper side of the body. So little is known of the Palæozoic star-fishes and their relations to later forms, that all classifications must be regarded as provisional. Subdivisions have been based on the character of the so-called pedicellariæ. These are small pincer-like organs that occur in star-fishes and sea-urchins, on the surface of the test, as shown in the illustration below. The movable spines covering the surface of these animals, and varying in size from minute, delicate, bristle-like structures to long rods, which may be thin and pointed, or thick, or even globular, are familiar to all. The pedicellariæ are probably derived from the smaller spines; two of these united at the base by a muscle, and slightly curved so as to approach one another at the ends, form the simplest kind of pedicellaria; and, by gradual modifications of this type, all the varieties may be derived. Many uses have been ascribed to the pedicellariæ, such as holding pieces of food, or removing dirt from the surface of the test. In some sea-urchins they are provided with poison-glands, which seems to show that they serve as weapons of offence in those cases. It has been considered that in sea-urchins their chief use is to catch hold of fronds of seaweed and keep them steady until the spines and tube-feet can be brought into action. The inner surfaces of the forceps in the pedicellariæ are remarkably sensitive, and the blades close on any minute object immediately their inner surfaces are touched by it. It seems, however, that in spite of the amount of attention devoted to these organs, we do not yet understand all their uses. Besides spines and pedicellariæ, star-fish also have on the surface of the skin small tubular processes, containing an extension of the body-cavity. These have very thin, contractile walls, and doubtless serve to assist respiration. All star-fishes have tube-feet, but in some these have no suckers at the end, and in all cases those which are at the ends of the rays are used only as feelers, and are stretched in the direction in which the animal is moving. At the extremity of each arm is a single tube-foot, which is the first to be formed, and is known as the unpaired tentacle; this being always stretched straight out. Immediately above this tentacle is a small eye, coloured by red pigment, and protected by small tentacles.



PEDICELLARIÆ.
a, Two-jawed, closed; *b*, Two-jawed, open; *c*, Three-jawed. (20 times nat. size.)

Star-fish are sluggish animals, rarely moving of themselves, and staying for days in the same position. Those kept in tanks or in glass vessels prefer to cling to the side, instead of lying on the bottom. When disturbed, however, a star-fish can travel at a considerable pace. Those star-fish that have suckers crawl by means of their tube-feet, while those that have no suckers still use their tube-feet slightly, but also progress by the muscular movements of the rays. The short-armed *Asterina* and *Astropecten* can right themselves in less than a minute, and accomplish the act by raising themselves on the tips of four rays, and then turning a somersault by throwing over the fifth ray. *Asterias* takes rather longer, and

effects its purpose by first twisting over one or two of the rays and catching hold of the ground by the suckers. It then gradually turns over the rest of the body. *Cribrella* rights itself in the same way as *Asterias*, but, apparently because of the stiffness of its skeleton, takes much longer over the process. Star-fish, like other echinoderms, are a sociable class. Even the deep-sea forms sometimes live in swarms. Many shallow-water forms also are gregarious, and some species have been observed to pair at the breeding-season. The deep-sea star-fish, writes Alcock, "subsist largely on molluscs, the shells of which, along with the chitinous remains of prawns and amphipods, are often to be found in their stomachs; but some of the characteristic deep-sea forms appear to gorge themselves with globigerina-ooze." The shallow-water forms prefer hard ground, rocks, reefs, or beds of hard sand, where they find in abundance the molluscs and small crustaceans on which they feed.



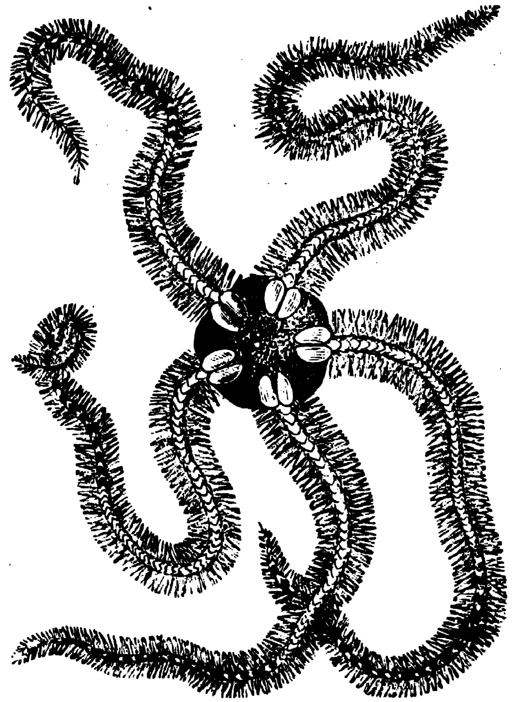
STAR-FISH TURNING OVER.

Between the Asteroidea and Ophiuroidea, the family *Brisingidæ* has been considered by some a link; but in all essential features of structure they agree with the Asteroids. Superficially they resemble the Ophiuroids in having long, thin, flexible arms, clearly distinguished from the small central disc or body.

THE BRITTLE-STARS,—Class **Ophiuroidea.**

The name Ophiuroidea, given to the brittle-stars, refers to their long serpent-like arms, which are attached to a relatively small and usually rounded body or disc. The digestive and generative systems do not extend into the arms, but are confined to the body; so that the arms are appendages to the body, rather than portions of it. They are cylindrical, and have no groove on the under side, such as exists in star-fish, but have little openings through which the tube-feet pass. In this class it is the arms themselves, and not the tube-feet that are used for locomotion. The tube-feet accordingly have no terminal suckers, but are very sensitive to touch, and probably assist respiration. The greater part of each arm is formed by a central axis of successive calcareous segments, not unlike the vertebræ of a back-bone. Each arm-ossicle or vertebra is, however, composed of two parts, one on either side, and united in the middle line; the successive ossicles being connected by pairs of strong muscular bundles, and articulating with one another by tenon-and-mortice joints. According to the degree of development of these joints, the arms have varied powers of coiling. Thus, in the *Cladophiuræ*, the ossicles have more or less saddle-shaped faces, so that the arms can be twisted round foreign

objects or rolled towards the mouth; in the *Streptophiuræ*, the faces of the ossicles have slight pits and processes, but none sufficient to prevent the ossicles being so twisted on their neighbours that the arms may be rolled up towards the mouth; in the *Zygophiuræ*, the faces of the arm-ossicles have articulating knobs and pits, which prevent the arms from being rolled up towards the mouth. These vertebral arm-ossicles are encased in the tough outer skin of the arm, in which are developed granules, plates, and spines, which are least definite and regular in the *Cladophiuræ*, most definite in the *Zygophiuræ*. The spines, which are clearly shown in the annexed figure of *Ophiothrix*, are borne on the side-plates of the arm, and aid the animal in locomotion. The integument of the disc also bears plates or scales of various sizes, often more or less covered with granules and minute spines. The precise arrangement of the plates on the top of the disc varies in different species; but five pairs of plates, known as the radial shields, are always present at the base of the arms, and are shown in the annexed figure. On either side of the arms where they join the disc, there is seen on the under surface a slit-like opening. These openings, known as the genital slits or clefts, are usually single but sometimes double; they lead into thin-walled pouches or bursæ at the sides of the rays. In a living ophiurid, the disc alternately expands and contracts, and thus water is pumped into and out of the pouches, through the slits. The entering water brings oxygen, which it exchanges, through the thin walls of the pouch, for the carbonic acid contained in the water of the body-cavity, and then goes out again by the return current. Hence the pouches are called respiratory bursæ. But they have another function, since the ovaries enter into them, and the ripe ova may either be carried out by the current through the slits, or they may remain and undergo direct development in the pouches themselves. Around the mouth are a number of short flat processes, or papillæ, serving as strainers, and keeping foreign bodies that are not wanted for food from entering the stomach. Round the mouth are also twenty tentacles, which are really the modified tube-feet of the two first arm-segments of each arm. They are in a state of continual movement, assisting the food to enter, and clearing away the undigested residue, which is ejected from the mouth.



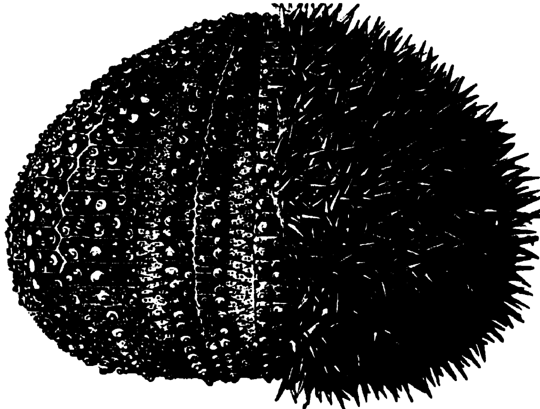
COMMON BRITTLE-STAR (⅔ nat. size).

The branched ophiurids, or *Cladophiuræ*, are sedentary, attaching themselves by coiling their branching arms around corals and suchlike animals; but can move when they please. The same mode of life is also affected by a few of the simpler forms; but, as a rule, ophiurids have considerable powers of locomotion, of which

they readily avail themselves. Most walk rather than creep, raising themselves on their five arms as upon legs; stretching out one or two arms in front, and drawing the rest of their body in the same direction. Even in a state of repose, the arms alone touch the ground, the disc remaining raised above it In other forms, however, the rays of the body undulate laterally, and produce a creeping serpentine movement. Rondelet wrote that the common brittle-star creeps by the flexuous movement of its rays in the manner of serpents, and, placed on dry land, never ceases to move them, until it casts them off in pieces, which, although separate, move by bendings, like parts of worms and the cut-off tails of lizards. The little *Amphiura*, which lives under stones, among the roots of seaweed, can turn its arms very quickly around its disc, and so form itself into a little ball; thus, if it be disturbed, it can roll and sink quickly into deeper parts of the water. Sometimes ophiurids are seen to progress by a kind of rowing motion of the arms.

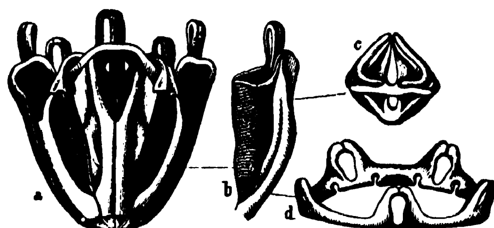
THE SEA-URCHINS,—Class **Echinoidea.**

The sea-urchins are the best known, as they are the most numerous of all echinoderms. The annexed illustration shows the test or shell of the egg-urchin, with the spines on the right side, but scraped away from the left. The plates of the test are seen to be covered with rounded tubercles of various sizes, and it is to these that the spines are attached by a ball-and-socket joint, surrounded by muscles that can move the spines in any direction. The tubercles do not, however, cover the whole test indiscriminately, but are disposed chiefly in five broad zones, extending from one pole to the other. Alternating with these are five narrower zones, bearing smaller and fewer tubercles, and pierced by small holes arranged in regular rows. Through these holes pass the tube-feet, which are all provided with suckers at the end. These latter zones are, therefore, the ambulacral zones; one of them being seen in the middle of the illustration. The other zones are called interambulacral, and one of them is shown on the left of the same illustration. All the zones converge towards the summit of the test, where the vent is situated in a circular space covered with membrane. This membrane contains a few irregular granules, and is surrounded by five large interradially placed plates, pierced by the ducts of the generative glands. One is also pierced by a large number of small water-pores, and is called the madreporite. Outside these five plates, and alternating with them, are five other plates, each situated at the top of an ambulacral zone, and pierced by the unpaired tentacles, which terminate the water-canals, and represent the unpaired tentacles near the eye at the ends of the arms of a star-fish. At the other pole of the body is another membrane, sur-

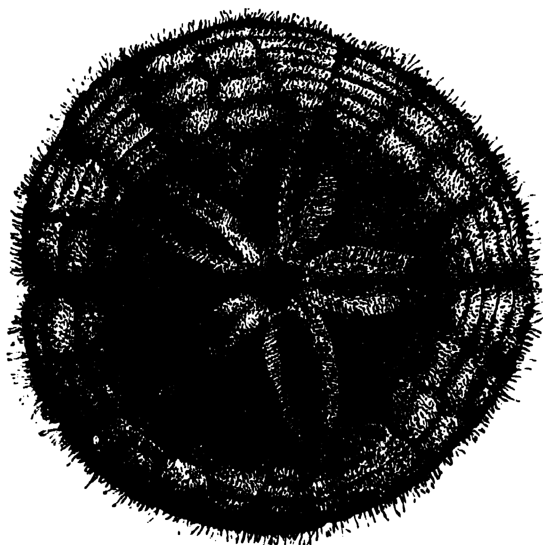


TEST OF EDIBLE SEA-URCHIN, WITH THE SPINES REMOVED FROM THE LEFT-HAND HALF (nat. size).

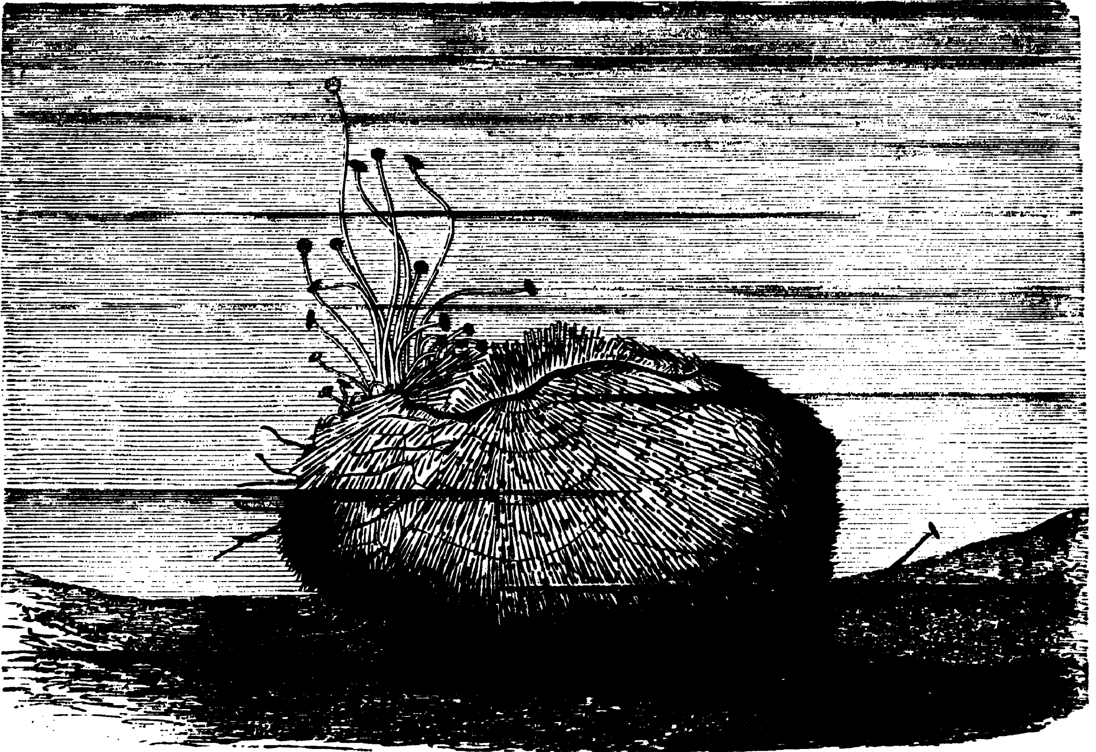
rounding the mouth-opening, through which may be seen five pointed teeth. These belong to a very elaborate masticating apparatus, shown in the illustration, and found in all the regular urchins, as also in the Clypeastrida among the irregular urchins. This consists of twenty principal pieces arranged into a five-sided conical mass, compared by Aristotle to a lantern (*a*). In the centre of the whole are five teeth (*b*, *c*), working in bony sockets, or pyramids, connected by muscles with one another, with the interior of the test, and with the arched processes, known as auricles (*d*), that surround the mouth-opening. There are yet other calcareous pieces connecting the pyramids together, and serving as attachments for yet other muscles. Such a sea-urchin as that described, preserves as much as any echinoderm the five-rayed symmetry of the group; but in many forms the five-rayed type is not so obvious, for the animal has become elongated along one of the axes, so as to have a superficial two-sided symmetry. This is naturally connected with constant movement in one direction, as though the animal had a head and tail; and such modification is found among those urchins that live on muddy bottoms, and especially in those from considerable depths. Not only is the test elongated, but the mouth moves forward to the front margin, and the vent downwards to the hinder margin, so as eventually to lie on the under instead of on the upper surface of the test. An earlier stage in this modification is shown in the illustration of the shield-urchin (*Echinarachnius*), and a fully developed one in the heart-urchin (*Brissopsis*), with its long tube-feet extended in the act of walking towards the left. These heart-urchins, as they move along through the sand and mud, scoop it up into their mouths, and pass it through the intestine, extracting on its passage such nutriment as the minute organisms it contains can afford. To enable them to scoop it up in this way, the hinder margin of the mouth is produced forwards in a kind of shovel shape, as is shown in the illustration of a *Pourtalesia* test from which the spines have been removed. These animals live at very great depths in the sea, and are the urchins most modified in this particular direction. Urchins of the heart-shaped type have short delicate spines, and move almost entirely by their long tube-feet, in the manner described; but the greater number of the regular urchins progress chiefly by the aid of their spines, which are much stouter, while the tube-feet often have the suckers very imperfectly



JAWS OF STONE-URCHIN (nat size).


SHIELD-URCHIN, FROM ABOVE (nat. size).

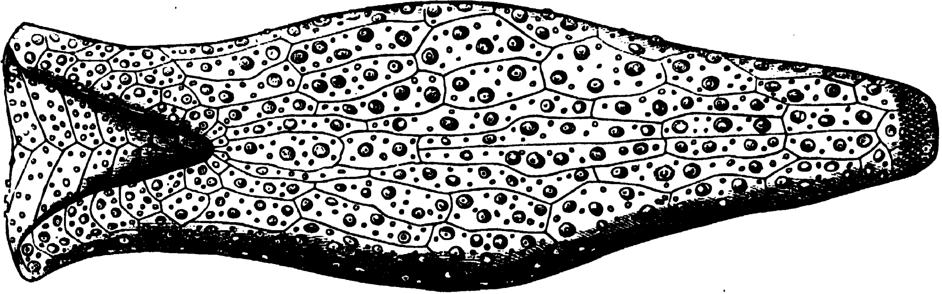
developed. The spines of sea-urchins also serve as organs of protection; but their efficacy varies much in different forms. For instance, *Diadema setosum* has fine sharp spines, 8 or 10 inches long, which prick one almost before one can see them, and can pierce the stoutest boot; their danger being increased by the gregarious habit of the animals. Some sea-urchins have poison-glands attached to their spines. It is the smaller spines that are protective, and they are placed for this purpose near the main openings and organs of the body, such as the vent, genital pores, and eyes; they also protect the ambulacra, and bases of the larger spines. A *Porocidaris* feeling itself free from danger, in well aërated water, walks from one side to the other, doubtless in search of food; its ambulacral tentacles being



FIDDLE HEART-URCHIN, MOVING OVER THE SAND TOWARDS THE LEFT (nat. size).

stretched out as feelers, and its long spines moving as described. The smaller spines are depressed to permit of the free movement of the larger ones, and those of the ambulacra raised to permit the extension of the tube-feet. If one slightly wounds the animal when thus expanded, the larger spines immediately stiffen on their tubercles, while all the smaller spines depress themselves, each over the organ that it is destined to protect. Though the tube-feet may not be used for locomotion, they are put to another useful purpose. If a *Strongylocentrotus* be placed in a tank with some dead shells or similar objects, it will raise them on to its back, and hold them there by means of the tube-feet, as a kind of concealment. Some sea-urchins cover themselves all over in this way with bits of seaweed, shell, and small pebbles, and so move about unobserved. Other sea-urchins do not move

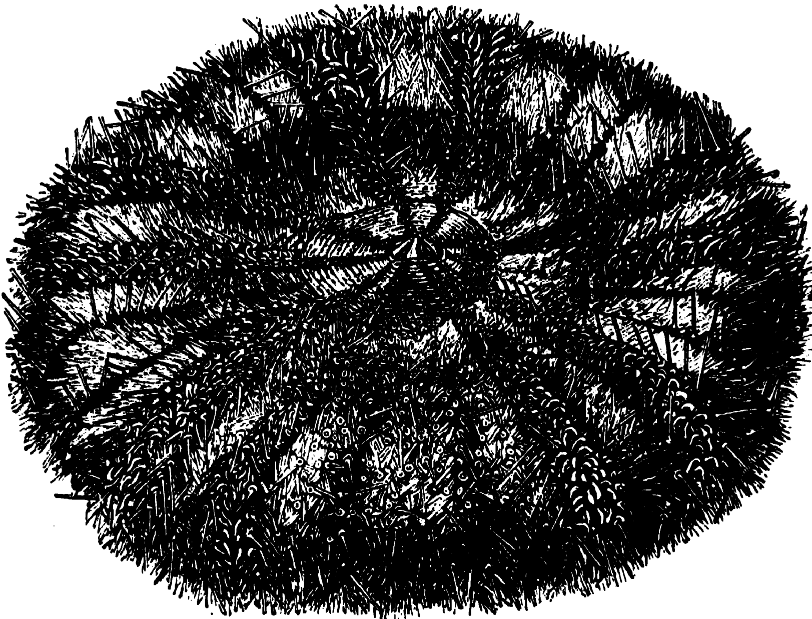
from place to place, but always stay in one spot, where they are generally found living in a hole. Sometimes the hole may have been there before the sea-urchins; sometimes may have been formed by the growth of calcareous algæ around the sea-urchin; but sometimes the urchin itself has bored the hole. This is accom-



PHIAL-SHAPED POURTALESIA; TEST WITH SPINES REMOVED (enlarged 4 times).

plished not by any acid secretion,—for on the west coast of Africa an *Echinometra* has been found boring into an augite lava,—but by the continuous movement of the teeth and spines. The common *Strongylocentrotus* is a well-known example of a boring sea-urchin. When the waves wash up against the urchin it sets its spines rigidly against the sides of its hole and so holds fast.

Although most of the sea-urchins have a rigid test, yet there are some in which the plates are only loosely joined together, so that the test is flexible.



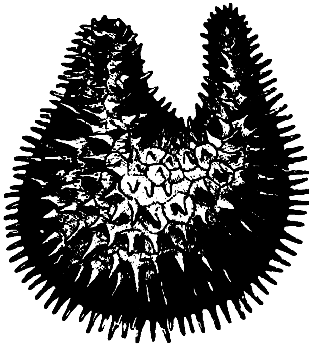
LEATHER-URCHIN (⅔ nat. size).

This is the case in an *Astropyga*; but is still more pronounced in the leather-urchin (*Asthenosoma*), and other members of the family *Echinothuridæ*. Respiration is effected in the regular sea-urchins by ten gills near the mouth. These are thin-walled ciliated extensions of the body-cavity protruding

between the membrane round the mouth and the plates of the test. In the irregular urchins some tube-feet are modified for respiration, becoming broad, flat, and somewhat lobed; the hinder end of the intestine seems to be respiratory in function. Some sea-urchins possess eyes. In a *Diadema* there are five ovate pigment-masses of a brilliant ultramarine blue, placed at equal distances around the vent. There are certain other peculiar bodies supposed to be sense-organs of some kind, called sphæridia, which are of microscopic size, and in structure not unlike tiny spines. They lie near the mouth and on the lower ambulacral plates, are often set in small holes, and are provided with special nerves. Perhaps they test the water in which the sea-urchin lives, and thus may be said to serve the sense of smell. Sea-urchins are both animal and vegetable feeders, and are even cannibals when opportunity offers.

THE SEA-CUCUMBERS,—Class **Holothuroidea.**

Sea-cucumbers are, as we have seen, elongated and worm-like creatures, with a mouth at one end and a vent at the other. The skin is leathery, and contains a comparatively small amount of calcareous matter. Usually this occurs in small spicules, which assume very definite shapes, such as the anchors of *Synapta*, or the wheels of *Chiridota*; but in such forms as *Psolus* the spicules increase in size, so as to form a plated integument. There may also often be a ring of calcareous plates round the gullet, five of which plates have the same relation to the radial water-vessels as the auricles around the jaws of a sea-urchin, and they likewise serve for the attachment of muscles. In such a common form as *Cucumaria planci* there are five rows of tube-feet passing from mouth to vent. The five-rayed symmetry is not obscured, and is traceable in the arrangement of nerves and muscles, although it does not affect any portion of the digestive or generative systems. Around the mouth, in *Cucumaria*, is a fringe of branched tentacles, connected with the water-vascular ring. In most other echinoderms, it will be remembered, a canal passes from this ring and opens to the exterior by a madreporite; and in a few holothurians of primitive structure this is similarly the case. But in *Cucumaria*, as in most, the connection with the exterior is lost, and the canal, with its madreporite, hangs down into the body-cavity. In *Cucumaria* the tentacles are used like a net to intercept floating organisms in the surrounding water. Many holothurians swallow a great deal of sand, and the intestines of those that live near coral-reefs generally contain fragments of coral. They usually attach themselves by their tube-feet to rocks or seaweed, and wave the tentacles around. *Holothuria atra*, which lives on the great Australian barrier-reef, inserts its hinder extremity within a crevice of the rock, into which on being disturbed it speedily retreats.



U-SHAPED SEA-CUCUMBER
(⅔ nat. size).

Some curious modifications of form have taken place among the holothurians. In the plated sea-cucumbers (*Psolus*), of which a specimen is illustrated on p. 314,

the animal has become flattened, and the tube-feet restricted to three out of the five ambulacra, and by these three the animal creeps about, or holds itself fixed to the rock. A similar modification is carried to excess in the deep-sea holothurians known as Elasipoda. Here, as in the illustrated *Scotoplana*, there are a couple of rows of thick tube-feet, forming little stumps, with which the animal moves, as a centipede moves by its legs. In front there is a sort of funnel or scoop formed by the short tentacles, while a few of the tube-feet form long horns or feelers on the upper side. In the deep-sea *Psychropotes*, on the other hand, mouth, vent, and tube-feet are confined to a flat sole; while the posterior part of the body is

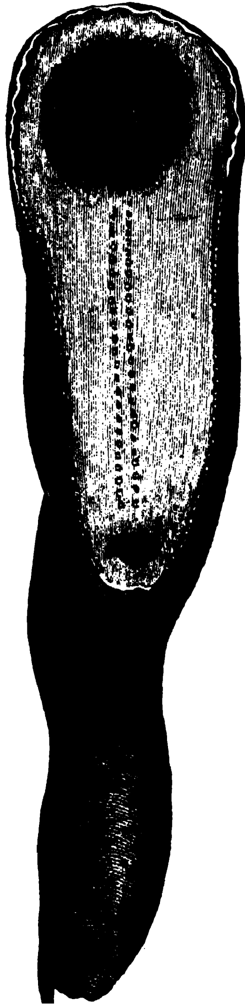


A DEEP-SEA HOLOTHURIAN, *Scotoplana* (nat. size).

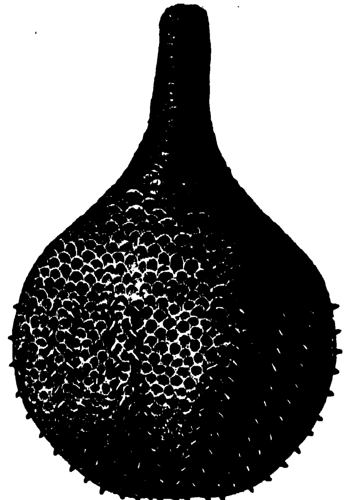
extended in a long tail. Some holothurians live in mud; and by reason of constantly keeping both mouth and vent above the surface their bodies have become curved in U-fashion, as seen in the U-shaped *Ypsilothuria* (illustrated on p. 312). This is carried still further in the club-like *Rhopalodina* (illustrated on p. 314), a form shaped like a cherry, with a thick stalk; the openings of both mouth and vent being at the top of this stalk. A yet stranger modification is the holothurian described under the name *Pelagothuria*, which lives in the East Pacific, on the surface of the ocean. It has no calcareous spicules, the longitudinal muscles being mostly changed into a jelly tissue. Around the mouth the body is extended into a kind of disc, prolonged into thirteen to sixteen feelers. The animal swims by the movements of this disc.

Holothurians have no means of offence, but protect themselves for the most part by assuming the colour of their surroundings. The huge *Synapta besseli*, which reaches a length of 6 feet, has a habit, when taken in the hand, of squeezing the fluid contents of its body towards the portion that is grasped, till it becomes too big to hold. Some, when much irritated, seem to fade away and dissolve by

breaking up their tissues; while others have an objectionable habit of shooting out a part of their intestines in long viscous strings; and it is owing to this that a common British form has gained the name cotton-spinner. It has been suggested that this habit has been acquired in connection with the presence in the intestine of small parasites, and these in their turn have their habits affected according as they live in holothurians that are or are not cotton-spinners. Among the parasites of holothurians should specially be mentioned a little fish of the genus *Fierasfer*, that inhabits the intestine of some species, and has its food provided for it by the holothurian; this fish is described on p. 438 of Vol. V.



A DEEP-SEA HOLOTHURIAN, *Psychropotes* (⅔ nat. size).

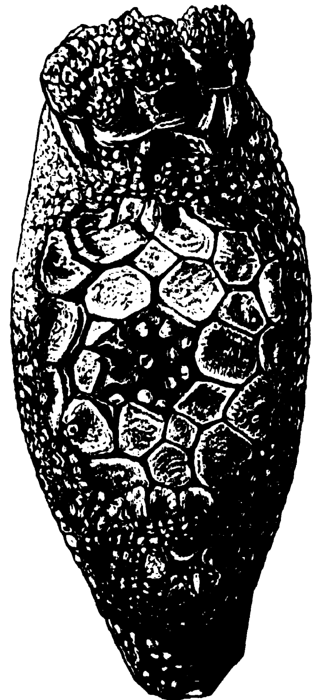


CLUB-LIKE SEA-CUCUMBER (*Rhopalodina*) (nat. size).

Holothurians are of interest, as furnishing a food known as trepang, which ranks with edible birds' nests among the delicacies of a Chinese table. The fishing for trepang, or *bêche-de-mer*, as the holothurians are called by the Portuguese, takes place very largely in Oriental countries, and is being extended to the Barrier Reef of Australia. All kinds are not equally esteemed, for some have too much calcareous deposit in their skin, and others get rid of their insides, and so become too lean.

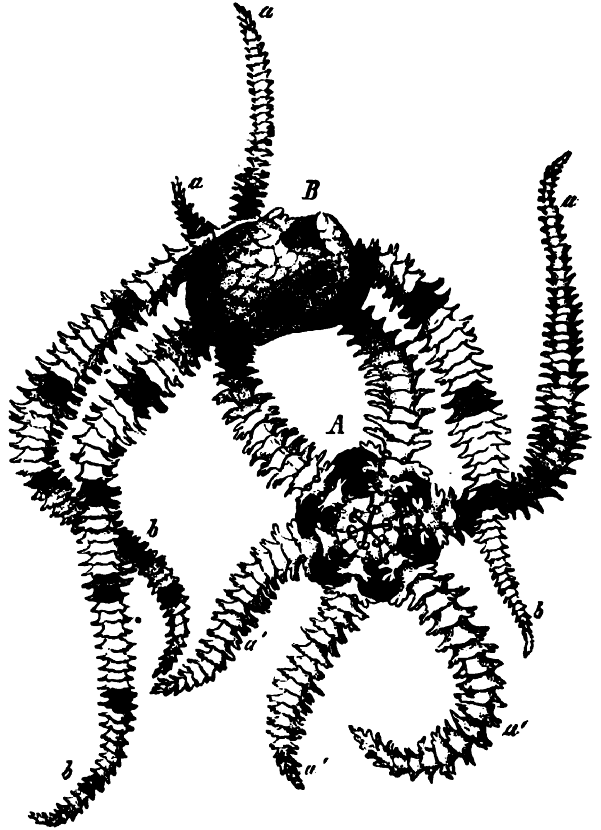
Development of Echinoderms

Few things about echinoderms are more remarkable than their modes of reproduction, which include both a sexual method, from the fertilised egg, and also one by budding or splitting of a single individual into two. Many echinoderms, as we have already seen, have the curious power of breaking off portions of themselves; as the brittle-star or crinoid can break off their arms. Also they are able to eject the whole or a part of their viscera, a faculty which has been specially developed in some of the holothurians. It is still more remarkable that the portions so broken off can be grown again, and that they



A PLATED HOLOTHURIAN (*Psolus*).
Some plates of the back, above the brood-pouch, are removed (enlarged 3 times).

themselves can, in many cases, grow fresh bodies, and become complete individuals. A star-fish of the genus *Linckia* commonly avails itself of this faculty; and it is by no means rare to find big arms with a small body at one end, and four little arms growing out of it; these are known as comet-forms. This power of reproduction is probably due to the extension of all the systems of the body into the arms: the arms of brittle-stars, which do not contain all the systems of the body, have not been known to reproduce individuals. In some cases echinoderms have been seen definitely to reproduce themselves by fission or splitting in half. Such division is well known to take place among the sea-cucumbers; and it is believed by some to take place even in brittle-stars; the specimens of the six-armed green snake-star (*Ophiactis*), shown in the annexed illustration, being thought to represent the result of such a process. The specimen *A* consists of two almost similar halves; but the three arms towards the bottom of the illustration, marked *a'*, are smaller than the others marked *a*, and indicate that this half is the later grown. The specimen *B*, which is seen from the back, has only just separated itself from its other half. The separation appears to take place by a forcible though spontaneous rent, and the edges of the wound subsequently grow together, and not merely heal up but reproduce the lost parts of the animal. As a rule, however, echinoderms reproduce by the ordinary sexual methods; although this, too, presents peculiarities. Just as a butterfly does not develop directly from the egg, but passes through the intermediate larval stage of the caterpillar, out of whose chrysalis the butterfly springs, so the sea-urchin or the star-fish egg gives rise to a larval form, in whose body, as it were, the mature form is developed. The particular shape of the larva varies in the different classes of echinoderms: but the differences are not essential, and it is clear that all the larval forms are modifications from one primitive type. The changes passed through in the development of the common sea-urchin (*Strongylocentrotus dræbachiensis*) are depicted in the illustration on p. 318, in which the drawings are very greatly magnified.

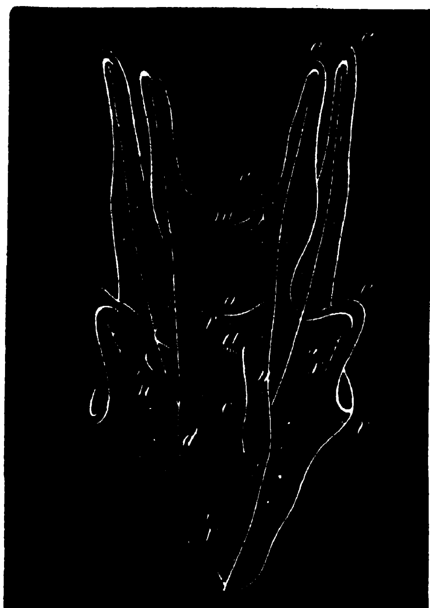


GREEN SNAKE-STAR (enlarged 5 times).

The fertilised egg divides and subdivides until a round ball of cells is formed. This is then pushed in at one end, as one might push in a soft indiarubber ball, so that there is formed a little sac with a double wall to it (stages 1, 2). Stage 3

shows this in outline as though transparent; and one sees the opening *a* turned downwards, and the canal *d*, which foreshadows the intestine. At the upper pole

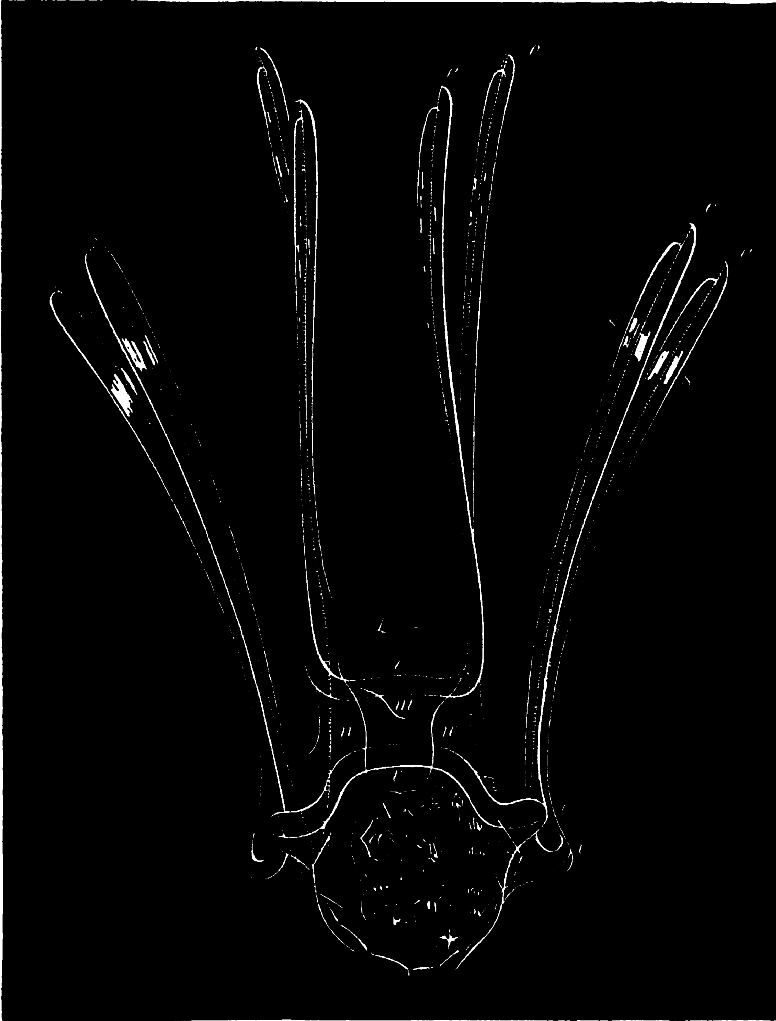
DEVELOPMENT OF A SEA-URCHIN (stages 1–8).



DEVELOPMENT OF A SEA-URCHIN (stage 9).

of the embryo, near the number 3, is a small tuft of cilia, by the motion of which the embryo swims about. In stage 4 this ciliated area is seen to have extended downwards to the letter *v*. The intestine now develops in such a way that the original opening (*a*) remains as the vent, the middle part (*d*) widens into a stomach, and a fresh mouth-opening (*m*) is pierced through at its upper end. This is seen from the side in stage 4, and from the front in stage 5. But before the mouth is formed, two ear-like processes (*w*) show themselves, which are important as being the beginnings of the ambulacral and water-vascular systems. There also appear a few delicate, symmetrically laced rods of carbonate of lime, which by and by grow into the skeleton of the larva, in shape something like an inverted easel. The two lower ciliated

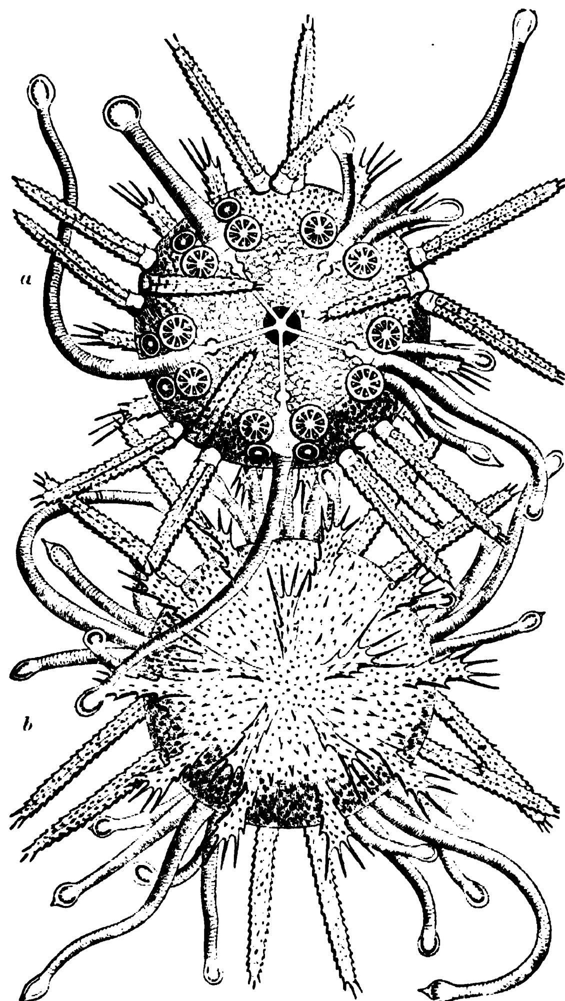
bands now grow towards one another, so that the vent comes to lie beneath them (stages 7 and 8). They also join themselves to the two upper bands, so that there is formed a single zone of cilia, which persists to the end of the larva's life. Already can be distinguished the beginnings of the apex and of the processes (*e*), which finally lengthen into the arms that give such a strange appearance to the larva, in the sea-urchins and also in the star-fish and brittle-



DEVELOPMENT OF A SEA-URCHIN (stage 10).

stars. In stage 8 can be seen, at *b*, the pore that admits water to the water-vascular system; and at this point will lie the madreporite of the future sea-urchins. The next illustration shows all these parts in a rather more advanced stage: *a* is the vent; *c*, the hinder intestine; *d*, the stomach, around which a deposit of spicules indicates the first beginnings of the body of the sea-urchin; *o*, the gullet; *m*, the mouth; *e*, the arms of the larva; *r*, the calcareous rods that support them; *v*, two more strongly-developed and slightly projecting portions of the ciliated band; and *w*, the water-vessels. The larva in its full development is shown in the

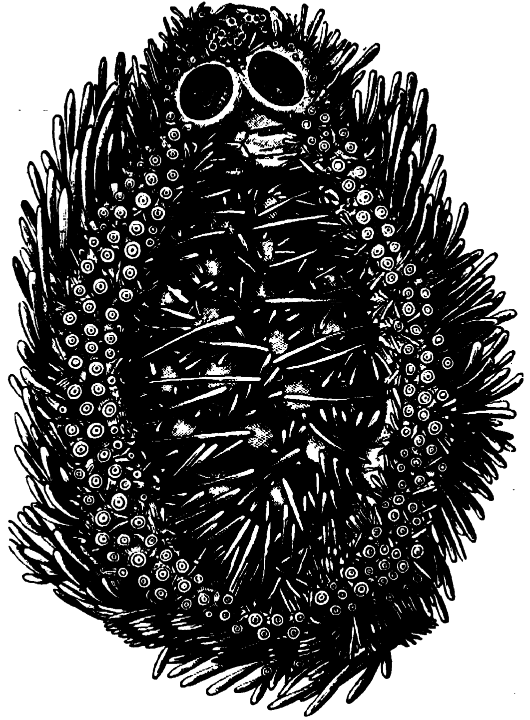
illustration on p. 317, in which the letters have the same meaning. This larval form is called a *Pluteus*, on account of its frequent changes of shape, as it swims about with its arms constantly moving. It will be noticed that through the whole of its development it retains a two-sided symmetry, such that if cut down the middle it would be divided into two precisely similar halves. This is very different from the five-rayed symmetry of the sea-urchin, and the difficulties arise both in this class and in the others when we try to discover how the five-rayed form was produced from the two-sided one.



YOUNG SEA-URCHIN (*Strongylocentrotus*). *a*, From below *b*. From above (enlarged 20 times).

From this larva only the stomach and the water-vascular system are continued into the sea-urchin, whose prickly body is now being formed around the stomach of the larva; and it is in just those two systems, especially in the madreporite and in the intestine, that we note in the adult the traces of the primitive bilateral symmetry. When the little body of the sea-urchin, which at first is like a flat box, has become provided with a mouth of its own, and with a circlet of comparatively large spines, then the parts not necessary to the new structure disappear. The calcareous skeleton of the larva is absorbed, and the lime salts thus set free help to build up the test of the sea-urchin. The arms sink in, and at last the outer larva remains as nothing more than a skin over the test of the urchin. The mode of life of the little sea-urchin, about one millimetre in diameter, is now completely altered! It is no longer carried about through the water, but crawls by means of its tube-feet and its spines, as shown in the above illustration. We cannot here follow the further changes that it undergoes; but a study of those later stages is of great importance. For by means of such study Agassiz has shown that many supposed genera are nothing more than undeveloped forms of well-known species, and he has thus been able to work out the relations of species and genera to one another. It is not, however, all echinoderms that pass through these curious larval stages, for in many species the young are developed in the shelter of the mother. We have already seen this to be the case with many brittle-stars, which are protected in the so-called genital

bursæ. In a sea-urchin (*Hemiaster philippi*) there are depressions between the ambulacra, which are called brood-pouches; for in these the young develop from the egg, covered over by the spines of the parent, as in the annexed illustration. In some holothurians the young are attached to the body of the parent, as in *Cladodactyla crocea*; but in others, as in *Psolus ephippifer* (shown on p. 314), they live on the back of the mother under some large mushroom-like plates. Some star-fish, too, such as *Pararchaster*, have a kind of tent of plates in the middle of the disc, where the young grow up as in a nursery.



BROOD-POUCH OF A SEA-URCHIN (enlarged 5 times).

The direct development from the egg to the adult in these protected forms, seems to show that the elaborate shapes of the various larvæ have been developed secondarily for the special purpose of transporting the young and aiding in the dispersal of the species, and, therefore, that they are not relics of any ancestral forms. There can, however, be little doubt that the echinoderms were originally derived from some form or forms with a two-sided symmetry; and it is certainly curious what a close resemblance their assumed primitive larval form presents to the larva of *Balanoglossus*, the worm-like animal described on p. 573 of the last volume, and considered by many authorities to be in the ancestral line of the Vertebrata.

F. A. BATHER.

CHAPTER IX.

THE MOLLUSCS OR SHELL-FISH,—Subkingdom **MOLLUSCA.**

SCIENCE is never stationary, and consequently the scope of many groups of the animal kingdom has considerably altered since they were defined by their original founders. Such has been the case with the Mollusca of Cuvier. Besides the animals which constitute this subkingdom, as now understood, he included in it the Tunicata, Brachiopoda, and Cirripedia—branches of the zoological system, which more recent anatomists have long since removed elsewhere. At the present time the Mollusca comprise only such forms as the octopus, cuttle-fish, etc., all the marine shell-bearing animals of the whelk tribe, and other kinds, land and fresh-water snails, slugs, the tooth-shells, and bivalves of every description. The number of known species is very large, and fresh forms are constantly being discovered. Probably some fifty thousand recent species have already been described, the number of aquatic being more than double that of the terrestrial species. The aquatic kinds, however, will eventually be found to preponderate still more, for the sea appears to be inexhaustible in the production of new forms. It matters not in what ocean the dredge is let down, be it to a great depth, or in shallower water, something new is certain, sooner or later, to be gathered in. Drop the dredge to three thousand fathoms (more than three miles), and still molluscs are met with, and the extreme depth to which molluscan life extends has yet to be ascertained. The great coast lines of South America, Africa, Asia, and parts of Australia have been but imperfectly explored for the smaller kinds of Mollusca; for whenever a limited stretch of coast is carefully searched by the conchologist, considerable numbers of new species are forthwith discovered. On the contrary, with the terrestrial forms the case is different. They are more easily acquired, as they come under actual vision, and all the inhabitants of a given district can in course of time be known.

Definition. Molluscs are soft, cold-blooded animals, without any internal skeleton; but this is compensated for in the majority of cases by an external hardened shell, which serves at once the purpose of bones and as a means of defence. Their bodies are not divided into segments like those of insects and worms, but are enveloped in a muscular covering or skin, termed the mantle, the special function of which, in the majority of species, is the formation or secretion of the shell. Molluscs are more or less bilaterally symmetrical; but this bilateral symmetry in some cases, particularly among the Gastropods, is to some extent obscured by the contortion of the body. The foot, which serves the purpose of locomotion, or is used in burrowing in sand, wood, and rock, etc., is an organ highly characteristic of most Molluscs. The shells, in the vast majority, consist

either of a single piece, as in the snail, whelk, etc., or of two portions (valves) as in the oyster, cockle, and most other bivalves. In one group, however (*Chitonidæ*), the shell takes the form of a series of eight adjacent plates, and in one group of bivalves (*Pholadidæ*) there are one or more accessory pieces in addition to the two principal valves. In the bivalves, with one or two exceptions, the shell is always external. Not so with the univalves, in some of which it is quite concealed beneath the skin, in others it is partially so. Shells are mainly composed of carbonate of lime, with a small admixture of animal matter. Their microscopic examination has revealed a great diversity of structure. Some are termed porcellaneous, others horny, glassy, nacreous, and fibrous. The shell is essential to the life of the inhabitant, it forms part of its organisation, and if it be removed, death ensues sooner or later. Although Molluscs have the power of repairing injuries to their shells, no case is known of a species removed from its shell having secreted a fresh one. Many shells exhibit an outer coat of animal matter termed the *periostracum*. It is generally of an olivaceous tint, but varies considerably in thickness and appearance. It is quite smooth, or of a velvety or silky aspect, or it may be produced into hair-like extensions. Its special function is the preservation of the shell from atmospheric and chemical action. Were it not for the periostracum, the shells of fresh-water molluscs would in time be dissolved by the carbonic acid gas with which water is more or less saturated. Owing to the thinness of the periostracum, or to its having been worn away, the apical portion of many fresh-water spiral shells and the tips or beaks (umbones) of the bivalves are frequently more or less eroded through this chemical action.

Growth. The shells of gastropods are enlarged with the growth of the inhabitant by the addition of fresh layers to the margin of the aperture, so that a shell which at its birth had only two volutions or whorls, may eventually consist of about a dozen. The growth of bivalves is more readily understood, being effected by additional concentric deposits along the outer margin of the valves. The adult condition of many shells cannot be detected by a superficial inspection. This is particularly the case with the bivalves. On the contrary, a little experience soon teaches us to recognise in the majority of cases if a gastropod shell is immature; but even among this class there are many exceptions where the most practised eye would fail to determine the period of growth.

Many shells exhibit conspicuous prominences on the surface in the form of spines and ridges, and it is a great puzzle to the uninitiated how this ornamentation is produced. It is, however, a very simple matter. Wherever a spine occurs on a shell we may be certain that it resulted from a corresponding filament or process upon the edge of the mantle, and these processes may be brought into use only periodically. A striking example of this periodic formation of spines occurs among the typical *Muricidæ*. On the contrary, spines or extensions may occur only upon the lip or edge of the aperture when the shell has arrived at maturity, and consequently we may assume that the necessary prolongations upon the edge of the mantle for the secretion of such spines are only developed at this period of the mollusc's life.

The diversity in shells with respect to form, size, and solidity is simply enormous. What resemblance, for example, is there between a *Chiton* and a

Dentalium, or a *Carinaria* and a *Turritella*, and among the bivalves between a *Pholas* and the hammer-oyster (*Malleus*). The difference in size is still more remarkable, some microscopic forms weighing not more than the fiftieth part of a grain, whereas the gigantic *Tridacna* occasionally turns the scale at over 500 lbs.

As every mollusc has a history of its own,—a certain course to pursue in the living world,—its means of existence and propagation will be found sufficient, although to the human eye the chances against it may superficially seem overwhelming. The glassy *Carinaria*, regarded as a dweller on the surface of the ocean, would seem ill-adapted to withstand the buffeting of storms at sea; and so it is, but there is very little doubt instinct has taught the mollusc the proper moment, and the sufficient depth to descend from the surface, to be safe from the tempest's violence. The dweller on the seashore, open to the onslaught of the same unpitying foe, defends himself with a stronger abode. What dash of the waves upon the undefended rock could in the slightest affect the conical shell of the limpet? In very deep water the tendency to tenuity in the molluscan shell is plainly apparent, yet there are species dwelling at depths beyond the influence of surface storms, the shells of which present considerable strength and solidity. We may ask how and why is this? Although we may not in all cases be able to answer these queries from actual knowledge, certain is it, that reasons, probably very near the truth, are easy of suggestion. For example, the large *Cyprina islandica* and the heart-cockle (*Isocardia cor*) of the British seas possess shells of considerable strength and solidity. These, being molluscs of large size, would prove dainty morsels to the hungry haddock or other fish, if they were unprotected by a powerful shell and their extermination thus prevented.

Coloration.

The varied colours of shells are due to glands situated on the margin of the mantle. In most cases the colour markings are placed on the outer surface of the shell, beneath the periostracum, but occasionally the inner layer of porcellaneous shells is of a different colour to the outer. This is well instanced in the helmet-shells (*Cassis*), which are employed by the carvers of shell-cameos to produce white or rose-tinted sculptures upon a dark ground. The colour in some shells is liable to extreme variation. Take, for example, the common hedge-row snails, *Helix nemoralis* and *H. hortensis*. Here we find the ground-colour yellow, brown, pink, white, lilac, and various intermediate shades, and the bands which are usually brown, and normally five in number, may be altogether absent or vary from one to six, their position also being equally variable. This diversity in colour-markings results from the different position of the pigment-glands upon the mantle margin, but the cause of this variation in the position has not been ascertained, although it may be presumed; nor is the reason known of the difference of the ground-colour, which may occur among specimens of the same colony. White, black, red, green, yellow, olive, purple, slate-blue, and brown form the common ground-tints of shells, but pure blue is a colour hardly ever met with in the shells of molluscs. One or two species of land-shells (*Corasia*) from the Philippine Islands more nearly approach this tint than any other molluscs, but even in these there is a slight admixture of green. On the contrary, blue is a colour more commonly seen in the soft parts. The colour of the shell does

not necessarily correspond with that of the mollusc. The latter may be of an intense black, the shell being quite white; the "animal" may be a most brilliant creature with a variety of many colours, and its test merely of some uniform sombre hue. Very gorgeously painted shells are, however, generally indicative of highly coloured inhabitants.

That light and warmth are great factors in the production of brilliant colouring is beyond question. This is conclusively proved by the results of deep-sea dredging. Whenever great depths are reached, where darkness reigns, and the water is intensely cold, the molluscan inhabitants are without colour, or of very sober tints, although the periostracum, generally greenish or olivaceous, is scarcely modified under these circumstances.

Age.

Our information with regard to the duration of life in molluscs is very limited. Although certain species of land-shells have been kept alive in confinement for four or five years, or even longer, we cannot assert that they exist for so long a period under natural conditions. The length of life of individuals, as well as of different species, is probably very variable, some doubtless attaining to a good old age. Such a species as the giant clam (*Tridacna*), for example, it is rational to conclude must have a very lengthy term of existence, for, although the growth may be rapid, the formation of a shell weighing 300 or 400 lbs. must surely be the work of years; and, moreover, when the process of growth is ended, we know not for what period the shell may continue to live. It is likely that most land-molluscs are full grown in a year or two, but the term of their existence, after this, is probably very variable, according to the species. A specimen of the common periwinkle has been kept in an aquarium for nine years, but this scarcely indicates the limit of life of this species under natural conditions. Its average duration may be longer, but probably shorter. In connection with the length of life of molluscs, mention should be made of the long periods some of the species are capable of existing without food in a state of torpidity.

In cold climates land-snails bury themselves in winter-time in the ground or beneath dead vegetation, and in hot climates they assume a torpid condition in the hottest and driest season of the year, closing up the aperture of the shells with a temporary lid or door (called an *epiphragm*). Some of these summer-sleepers display great tenacity of life, many cases being on record of species which have lived for two, three, or even five years in a torpid state, without food of any description. Perhaps one of the most interesting instances, is that which has so often been quoted, of the specimen of the Egyptian desert-snail (*Helix desertorum*), which was fixed to a tablet in the British Museum for four years, and was discovered to be still living. Some fresh-water forms also are capable of living out of their native element for a considerable time. A species of Australian *Unionidæ* has been known to exist out of water for over a year, and some kinds of *Ampullaria* have lived for months after being taken out of their native rivers.

Reproductive System.

The sexes are distinct in some molluscs, and united in the same individual in others, but reproduction is in all cases effected by means of eggs. These are usually secreted or attached in some suitable position, but in some instances the ova are hatched within the oviduct of the parent, as in the fresh-water pond-snail (*Vivipara*); and probably in most bivalves the eggs are

retained within the parent shell until hatched. The ova of some of the gastropods, enclosed in capsules, are deposited in masses, and some of these form very remarkable and complicated structures. The number of eggs contained in some of these clusters is enormous. As many as forty thousand have been estimated in a mass, deposited by a single squid. The common whelk occasionally also piles up an enormous heap of capsules, as many as five or six hundred being massed together, each capsule containing several hundred eggs. Land-snails, in comparison with marine forms, produce comparatively few eggs. Some of those deposited by the large South American species are in a few cases half an inch to an inch in length, and have a strong calcareous shell. On the contrary, the productive power of some bivalves is enormous, the ova being counted not by hundreds but by hundreds of thousands, and even millions. The ova of molluscs may be gradually developed into the form of the adult, or there may be a free-swimming ciliated larval stage, or a special larval form as in the fresh-water mussel.

Food.

Molluscs are both vegetable and animal feeders, but probably by far the greater number of gastropods are carnivorous. Bivalves imbibe a mixed diet of infusoria and microscopic vegetables. The carnivorous species of gastropods principally attack other kinds of shell-fish, bivalves being especially appreciated. Some however, like the common whelk, will feed on dead fish and carrion of any description. Many of them are mere cannibals, and attack their own kith and kin. Out on the high seas the glassy *Carinaria* enjoys the succulent jelly-fish, and the squids and cuttles are a terror to many pelagic fishes. The octopus, like the gastropods, is partial to a bivalve meal, and a repast on shrimps and other crustaceans is a daily occurrence. Most land-shells are herbivorous, but a few are carnivorous, preying chiefly upon their plant-eating relations, and one curious slug lives exclusively on living earth-worms.

Organs of Sense.

Most molluscs which are provided with a more or less distinct head, namely, the cephalopods and gastropods, are furnished with visual organs, but the majority of bivalves (Pelecypoda) are sightless. Although an auditory apparatus exists, they appear almost insensible to sound. It is certain that most forms are endowed with the sense of smell, although the anatomist has frequently a difficulty in discovering the position of the olfactory organ. Land-molluscs appear to recognise their proper vegetable food by the smell as well as the taste, and the carrion-feeding whelks are probably attracted by odour. The senses of smell and taste are probably but imperfectly developed in the bivalves, which scarcely possess the power of selection as regards their food.

Locomotion.

Molluscs exhibit various ways of progression. Some are free-swimmers, like the cuttle-fishes and squids, pteropods, heteropods, and a few bivalves; others are mere crawlers, like snails and whelks; and some creep along, but beneath the surface of the water. The *Melampus* moves onwards after the fashion of a looper-caterpillar, and the bivalves either crawl upon their foot, or progress by a jerking or leaping movement. Many species, like the limpet, *Saxicava*, and *Pholas*, are very sedentary in their habits, and others, which in their early career are active, in after life are stationary in their permanent abodes.

Uses in Nature and to Man.

Molluscs form a large item in the food of many mammals, birds, reptiles, and fishes. Terrestrial forms are devoured by rats, ducks,

thrushes, and other birds; by lizards, toads, snakes, and even by certain kinds of carnivorous insects. The fresh-water forms are consumed in vast quantities by water-birds of every description, by fishes, frogs, water-voles, and other mammals, and aquatic creatures of various kinds; and every seashore is constantly ransacked by flocks of sea-fowl for the repasts of shell-fish it affords. Out in the depths of the ocean many kinds of fishes, especially cod, haddock, gurnard, soles, and mullet, are great devourers of molluscs, which ever fall a prey, not only to one another, but also to crabs, holothurians, sea-anemones, and star-fishes; and, finally, among the pelagic pteropods the Greenland whale seeks his daily sustenance.

Molluscs of all kinds, but especially the marine species, are much eaten by the natives of most countries; and even in Europe, although the oyster is the most highly appreciated, several other species are used as food. Molluscs are not only of importance to man as an article of diet, but they are serviceable in other ways. Their shells are employed as personal ornaments, and are used in the manufacture of fishing-tackle by some uncivilised people. In England and other countries many of the pearly species are manufactured into ornaments and various useful articles, and the beautiful pearls themselves, secreted within the tissues of the pearl-oyster, are esteemed as jewels.

Noxious Molluscs. The utility of the molluscs to man probably far outweighs the injury which is occasioned by a few kinds. In the foremost rank of the noxious species stands the *Terĕdo*, the great destroyer of submerged timber. The damage done to piers, boat-bottoms, and in fact to wood of any description which is located in the sea, is enormous, and there seems to be no effectual means of meeting the attack of these molluscs, except by covering the timber with metal-sheeting. The stone-work of breakwaters occasionally becomes more or less damaged by the burrowing habits of the *Pholas* and *Saxicava.* On land, snails and slugs commit onslaughts upon our crops and gardens, but these pests are more easily overcome than their marine relatives.

Distribution. Although this is a subject very fascinating to some, it is one which pre-eminently opens the gates of speculation. That species have certain geographical and bathymetrical limits in their distribution, may be an admissible fact in very many cases, but when the reason for this limitation is sought we are reminded how little we know of natural causes. That certain tracts of coast have their own peculiar inhabitants, and that the molluscs of the eastern shores of America, for example, differ from those of the west we must admit; but how this has come about, is matter of conjecture. We say that differences of environment, of food and temperature, are sufficient reasons to account for such things. On the contrary, we are met with the fact that certain species in a given genus have a much wider range than others, and we are fain to ask how this is brought about. The range of terrestrial molluscs is much more restricted than that of most marine forms. This is readily understood, as the means of dispersal are very different. The early stages of marine molluscs, if not free-swimming creatures, are liable to be carried great distances by ocean currents, or the action of the tides and wind. On the contrary, land-molluscs are creatures of slow progression, and are liable to have their distribution hindered, either by rivers, mountains, or seas. Consequently we find that island faunas, as regards the terrestrial species,

are mostly peculiar. It should be noticed that there are great differences in the molluscan land-fauna of different areas; that of North America being, for instance quite distinct from that of Central and South America.

It is a well-known fact that certain marine gastropods and bivalves inhabit particular parts of the sea-bottom. Some groups which occur between tide-marks, such as periwinkles and limpets, are termed littoral forms; others occurring below low-water mark, to about ten or twelve fathoms, are said to inhabit the laminarian zone, or the region where seaweed abounds. Below this, to about fifty fathoms, extends the coralline zone, so called from the abundance of corallines at this depth, which also furnishes a lurking-place for certain special forms. Beyond this is the deep-sea or abyssal region, of which certain species and genera are more or less characteristic.

Other races, such as the squids among the cephalopods, the various forms of pteropods and heteropods, and a few other gastropods, pass their lives far out at sea upon the surface of the ocean, and are termed pelagic species.

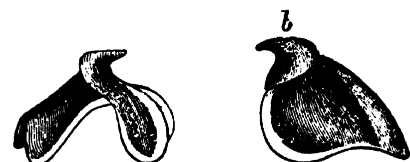
Classification. The Mollusca constitute one of the principal divisions (a sub-kingdom) of the animal kingdom, and it is subdivided into five principal sections or classes, namely, Cephalopoda, Gastropoda, Amphineura, Scaphopoda, and Pelecypoda. These divisions are founded on peculiarities in the general conformation of the animals, but it is also worthy of notice that the shells of the different classes differ widely in type. An important feature characteristic of the three first of these classes is a structure termed the *radula*. It is situated within the mouth, and is a kind of muscular tongue armed with teeth, and used in obtaining or comminuting food. The armature of this radula, odontophore, or lingual ribbon, is subject to great variation, and these differences have afforded characters for distinguishing various groups among the gastropods. There are a few genera of Gastropoda which are peculiar on account of the want of this masticatory organ, and it is also unknown among the headless bivalves.

THE SQUIDS, CUTTLE-FISHES, AND NAUTILI,—Class **Cephalopoda.**

The cephalopods are considered the most highly organised of all molluscs, and some of the species are remarkable for the enormous size they sometimes attain. They are exclusively marine animals, leading a predatory life out on the high seas, or among rocks in shallow water, or about low-water mark. The sexes are distinct. They may be recognised by the symmetry of their general conformation, the fleshy arms or tentacles situated around their mouths and in front of the head, and by their retrograde mode of progression, which is effected by the expulsion of water from a particular organ, termed the siphuncle or funnel. With one exception—the nautilus—none of the living cephalopods possess an external shell, and they are consequently termed naked molluscs. Nearly all decapods, that is, those species which are provided with ten so-called arms—have a straight calcareous or horny internal shell, which is a strengthening support to the back. *Spirula*, however, although a decapod, is an exception, and possesses a segmented shell, coiled up like a ram's horn, and concealed within the hinder part of the animal's body. The external shell wherein the female argonaut dwells is not the

equivalent of the shell of the nautilus, or of the gastropods. It is not attached to the animal by any special muscle, but held to the body by two of the arms, especially developed for this purpose. It is, in fact, merely a receptacle for the ova, but at the same time affords protection to the argonaut herself. All the rest of the octopods are without shells of any description.

The body of a cephalopod consists of a muscular sac, in the cavity of which the viscera are placed. In front of the body projects the head, which, in one of the two main sections into which the class has been divided—namely, the Dibranchiata, or those provided with only one pair of gills—is crowned with eight or ten fleshy muscular arms, in the midst of which the mouth is situated. This is armed with two strong jaws, in shape very similar to the beak of a parrot. They are curved, pointed, and of a horny substance in the two-gilled cephalopods, and somewhat calcareous in the four-gilled group. Within the mouth is the rasping tongue, covered with the sharp siliceous hook-like cusps or teeth, arranged in regular transverse series, one behind the other. The eyes, two in number, are placed on each side of the head, and are of enormous size in some of the decapods. On the ventral side the muscular sac is disconnected with the head, leaving a more or less wide opening admitting the water to the gills. The water is then expelled through the so-called funnel with more or less force, according to the requirements of the animal. If it be at rest, the expulsion of water is carried on very quietly, but, on the contrary, with much greater force if the animal is in motion. Besides water, other secretions from the body are extruded through the funnel, and especially a dark fluid secreted in a special ink-pouch. When disturbed or irritated, this ink is discharged by all cephalopods, excepting the nautilus, and is supposed to be a means of defence. Mixing with and clouding the surrounding water, we can well suppose that the attack of a pursuing fish might be checked, and the squid or cuttle effect its escape in the darkened fluid. The arms, or feet, of the octopods and decapods are more or less elongate and capable of movement in any direction, and are furnished on one side with numerous suckers, by means of which the animal holds on to anything that it may seize with such tenacity that the suckers themselves are liable to be torn away rather than loose their hold. They are often furnished at the edge with a toothed horny or calcareous ring, and connected with the arms by slender stalks. Cephalopods employ their arms in walking and climbing, and, owing to their position, have to progress head downwards when creeping on the sea-bottom. They are connected at the base by a skin, in some species extending some distance up the arms, and forming a sort of umbrella, which is doubtless of use in the capture of their prey. In the nautilus the arms are different, being short, pointed tentacles, unprovided with suckers.



UPPER (*a*) AND LOWER (*b*) PORTIONS OF THE BEAK OF A CUTTLE-FISH (*Sepia*).

The nervous system is more developed than that of other molluscs; it is concentrated around the gullet, and protected by a cartilaginous plate, a sort of rudimentary skull. The skin of the naked cephalopods is more or less thickly studded with points or dots of various colours. These pigment-cells are subject to alter their tint at the will of the animal, which, chameleon-like, assumes very different aspects

Some species also, which, when in repose or undisturbed, have the outer skin smooth, if irritated, become suddenly covered with conical tubercles or more or less elongate cirri.

Cephalopods are very voracious, feeding on fishes, molluscs, and crustaceans. Some species pursue and capture their prey, while others lie in wait and pounce upon it suddenly. Like every other group of animals, they have their enemies, being devoured in enormous quantities by cetaceans, fishes, and sea-birds. In some countries various species are esteemed as an article of food. Although about four hundred and thirty species of living cephalopods have been described, some of these are so inadequately defined, that the total, in round numbers, does not probably exceed about three hundred and eighty. These have been arranged in some seventy-five genera and fourteen families. About half the genera contain but a single species each, while nearly half the known forms belong to the three genera *Octopus*, *Sepia*, and *Loligo*. The cephalopods of bygone ages far surpass in number those which survive, and it is probable that we only know but a moderate proportion of the forms that have passed away in the various geological epochs; for what idea have we of the shell-less tribes which may have inhabited ancient seas, whose soft bodies have decomposed at death, leaving not a vestige behind? It is only those with internal or external shells which have been preserved; and what proportion of all the forms that have existed in all times do the fossilised remains known to us represent? The seas of our own times contain a large number of cephalopods, the existence of which in past geological ages cannot be proved; but, on the other hand, we know of great numbers of fossil genera and species of which there are no living representatives. The entire order of the Ammonoidea, which contains the well-known discoid, convoluted, chambered Ammonites, is entirely extinct, and it is a matter of uncertainty whether they should be classed with the dibranchiate or tetrabranchiate group, or be regarded as a distinct order by themselves. On the contrary, although the probability is that many existed in bygone ages, only a few fossilised remains of octopods have been identified with certainty, and the *Spirula* of to-day, which occurs in countless thousands, also appears to be unknown in the past.

Two-Gilled Group,—Order Dibranchiata.

Octopus Tribe, Suborder Octopoda,—Family *Octopodidæ*.

Commencing with the order Dibranchiata, we find this divided into the two suborders, Octopoda and Decapoda, according to the number of arms. Of these the octopods comprise several families distinguished by differences in the general build, the presence or absence of lateral fins, the number of rows of suckers on the arms, variations in the radula, etc. Since the establishment of public aquaria, in comparatively recent years, most persons have had an opportunity of seeing the unsightly octopus in its native element. An unpleasant, forbidding creature it is, contracting and swelling, or looking like a shapeless but living mass. We observe the eight tapering arms, with the two rows of suckers along the inner side of each, numbering about two thousand altogether in some individuals. We note the two staring eyes which seem ever on the watch, the funnel often exposed to view, and the mottled skin. About ninety species of octopus are known, which

occur in all seas. Variations in colour, the relative length of the arms, the size of the suckers, and the character of the hectocotylised or modified arm of the male, are among the distinguishing features of the species. Although we usually speak of the octopods as shell-less or naked molluscs, an indication of an internal shell is present, in the form of two short styles, embedded in the tissues of the mantle. These molluscs are solitary creatures when adult, but they are said to herd together



COMMON OCTOPUS.

in small companies when young. They live in the fissures of rocks, or hide away beneath great boulders. When they walk or creep, they elevate the sack-like body above the head, and progress slowly upon the extremities of the arms, which are a little curved near the tip. They can creep in any direction, but they prefer a side-way movement. On the contrary, if their progress in walking is comparatively slow, this is compensated by the rapidity of their movements when swimming. Body foremost, with the arms stretched beyond the head, they dart

backward with great rapidity, being propelled by the successive expulsions of water through the funnel. The arms are also made use of in swimming, and those which are provided with an extensive connecting web are the most effective swimmers. None of the octopods ever attain such enormous dimensions as some of the decopods, still some would be very dangerous foes to cope with beneath the water. Mr. J. K. Lord saw the arm of an octopus, captured at Vancouver Island, which measured 5 feet in length, and was as thick as his wrist; and M. Verany has given an account of a specimen which measured 3 metres from tip to tip of the outstretched arms. In the account of the molluscs, obtained during the voyage of the *Samarang*, Mr. Adams observes: "Octopi of enormous size are occasionally met with among the islands of the Meïa-co-shima group. I measured one, which two men were bearing on their shoulders across a pole, and found each arm rather more than 2 feet long, giving the creature the power of exploring an area of about twelve feet without moving, taking the mouth for a central point, and the extremities of the arms to describe the circumference."

In 1872 a very large specimen was stranded on the beach in the Bahamas, the arms of which were 5 feet long, and the weight was estimated at 200 to 300 lbs. The eggs of the *Octopus vulgaris* when first laid are small, oval, translucent granules, resembling grains of rice, not quite the eighth of an inch long. They are fixed along and around a common stalk, to which every egg is separately attached. These clusters vary in length according to the condition or age of the parent; those produced by a young octopus seldom exceeding three inches in length, and from twelve to twenty in number; but a large, full-grown female will deposit from forty to fifty of such clusters, each about five inches in length. In each of these clusters Mr. Lee counted about a thousand ova, so that a single octopus may produce at one laying a progeny of from forty to fifty thousand. The mother octopus watches, tends, and guards the egg-clusters for about fifty days, when the young emerge from the capsules. The sexes differ scarcely at all externally, but at the breeding-season a curious modification in the third right arm of the male is noticeable. It becomes swollen, and from it a long worm-like process is developed, furnished with two rows of sockets (the *Hectocotylus*). From the end of this process extends a slender, elongated filament. When its owner offers his hand to a female octopus, she not only accepts it, but keeps it, for this remarkable outgrowth is then detached from the arm of her suitor, and becomes a moving creature, having separate life, and continuing to exist for some time after being transferred to her keeping. The lost portion of the hectocotylised arm of the male is gradually reproduced, and in due time assumes its former appearance.

A second group of octopods (*Eledone*), which occurs in the Mediterranean and also on the British coasts, differs from the common octopus in having but a single row of suckers down each arm. In *E. moschatus*, the body is very changeable in form, pouch-like, oval, rounded, or pointed behind, smooth or warty, just as the animal likes. The great size of the mantle-opening, which extends a little over the back, is also remarkable. It is of a grey, yellow, or yellow-brown colour, with blackish spots, and a bluish edge to the web, and is met with on sandy and gravelly bottoms at all times of the year, more rarely among rocks. The rapidity with which the

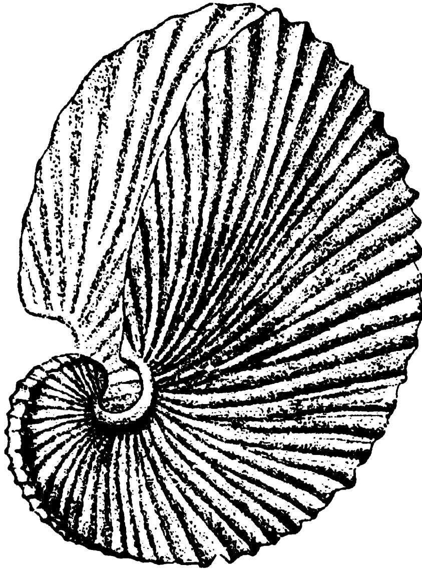
creature changes its colour is amazing. At the slightest disturbance a dark shade passes with the rapidity of lightning over the whole body. When it seizes its prey its entire skin becomes yellowish, studded with blackish symmetrical spots, and covered all over with conical tubercles. These molluscs have a strong musky smell, but in spite of this they are not unfrequently seen in the Italian markets, and purchased by the poorer classes.

Other Families. Other octopods are *Cirroteuthis*, *Pinnoctopus*, *Tremoctopus*, *Amphitretus*, and a few other allied genera, and *Argonauta*, several of which represent families by themselves. In *Cirroteuthis* the arms are connected throughout their entire length with a thin membrane, forming a sort of umbrella, at the bottom of which is the mouth. They are furnished with only a single row of suckers down the middle, but have a series of short cirri on each side, and the body is provided with two lateral fins. Seven species of this genus are known at present. *C. maura* was captured at a depth of thirteen hundred and seventy-five fathoms, and *C. pacifica*, off New Guinea, in two thousand four hundred and forty fathoms. *C. muelleri*, the type of the genus, occurs on the coast of Greenland. *Pinnoctopus* is remarkable for a fin-like expansion, extending the whole length of the body and uniting behind. In *P. cordiformis*—the only known species, and an inhabitant of the shores of New Zealand—the arms are long, and united at the base by a somewhat large membrane. *Tremoctopus* has no lateral expansions or fins to the body. The female has the two dorsal pairs of arms united by membrane, the two other pairs free; the male is without the interbrachial web; the head is large, having two pores on the upper and under sides. Nine species altogether have been described from the Mediterranean, North Atlantic, and Pacific. The genus *Amphitretus* is one of the remarkable forms obtained during the *Challenger* expedition. It possesses the character, unique among cephalopods, of having the mantle fused with the siphon in the median line, so that there are two openings into the branchial cavity, one on either side, whence the name.

Family *ARGONAUTIDÆ*.

The argonaut, or paper-nautilus, is one of the most interesting of the octopods, for around it for many years there hung a mystery and uncertainty. Some concluded that the shell was formed by another mollusc, and was merely taken possession of by the cephalopod, as a convenient abode or boat to swim in, or rather to sail in, for it was stated to raise aloft its two expanded arms to catch the breeze, and thus to voyage onward. This, for many years, has been proved to be mere fiction. The shell, with which only the female is provided, is of her own manufacture, and she swims just the same as other cephalopods. It is large, not adhering to the body of the animal, but retained in position by the application on the outside of the dorsal pair of arms, which are dilated and especially adapted for the purpose. Whether the argonaut ever quits its shell voluntarily or only by accident is unknown; specimens have been captured at sea without any shell, and they have lived for some time in that condition. A specimen was placed in an aquarium at a time it was out of its shell. This it re-entered, and remained in it the whole period, about fifteen days, it was in captivity. It invariably swam at the

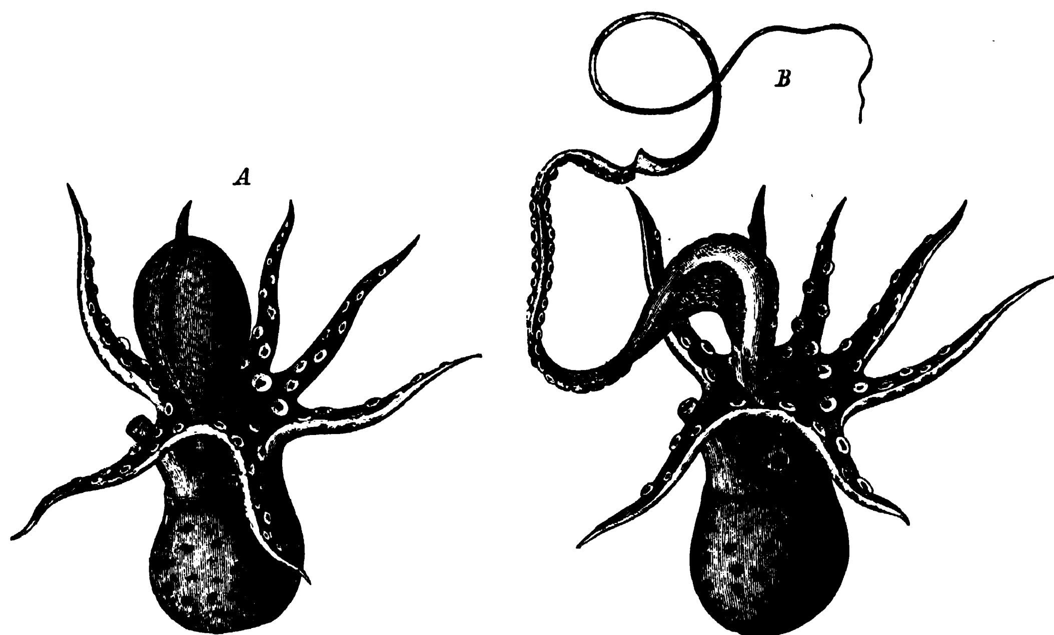
surface of the water with the coiled part of the shell upwards, a small portion being above the surface, to which the aperture was at right angles or inclined at an angle of 45°. It appeared calm and not subject to agitation like the octopus. It remained perfectly immovable, for no menace or excitement appeared to affect this appearance of tranquillity. Like the octopus, it exhibited chameleon-like changes of the skin, but not so rapidly or with such intensity as that animal. During all the time the specimen lived, all the arms, which have two rows of suckers, were kept within the shell, except the expanded posterior median pair. These, however, were also sometimes drawn within. Four of the arms were bent upwards, four downwards, leaving the mouth with its parrot-like beak exposed in the middle of their bases. Between the lower or ventral pair of arms the funnel was protruded, by means of which it propelled itself backwards. This specimen was not seen either to walk or swim with its arms; but other observers state that the creature walks or crawls along the bottom like a gastropod, by means of the non-expanded arms, carrying the shell above its body. The eye is round, bordered with black, and the circular pupil is also black.



SHELL OF FEMALE ARGONAUT.

The shell is supposed to be secreted chiefly by the palmate arms, aided by the mantle investing the body. It is developed some time after the birth of the argonaut, and a female has never been seen with a shell before it had attained about an inch in length. The male argonaut is very different to the female, and much smaller, being only about an inch in length. It resembles an ordinary octopus in having neither palmate arms nor shell. The arms are tapering and alike, excepting the third on the left side, which is specialised. This at certain times, having passed through various stages of development, is cast off, and attaches itself to the female, living a free and independent life for a considerable period. The eggs are small, numerous, and connected together by a network of filaments. They are deposited far within the shell towards the convoluted portion, and are practically in contact with the posterior part of the body of the parent. The shell therefore serves, not only as a retreat for the argonaut herself, but also as a nest for the eggs, and possibly as a nursery for the young. Very little is known with regard to the food of the argonaut. As its habits are very similar to those of the octopus, it seems probable that it may feed upon molluscs and crustaceans, which it might capture when crawling at the bottom of the sea. A captive specimen was fed with small live fish, which it ate with avidity. About eight species are recognised, which have a world-wide distribution, occurring in all tropical and warm latitudes. The shells of the different species are all of a white colour, and exhibit two distinct types of surface ornamentation, the one consisting of simple, smooth, radiating wavy ribs, the other in which these ribs are more or less broken up into nodules or

tubercles. *Argonauta hians* is the typical species of the former group, and *A. navicula* and *A. tuberculata* represent the latter.



A, MALE ARGONAUT (twice nat. size), WITH HECTOCOTYLUS ENCLOSED IN THE SACK; *B,* MALE ARGONAUT, WITH HECTOCOTYLUS FURTHER DEVELOPED.

Suborder **Decapoda.**

The Decapods form the second division of the two-gilled order, and differ from the Octopods, as the name implies, by the possession of ten, instead of eight, arms. The two additional arms differ from the rest in their greater length, and in having suckers only at the extremity. They are frequently completely retractile within pouches, and are used as prehensile organs in the capture of their prey. All decapods are provided with an internal shell. That of the living species is either horny—the so-called pen (*gladius*); or else calcareous—the bone (*sepion*) of the cuttle-fish. In *Spirula* the shell takes the form of a tube, beautifully coiled, and divided off into numerous air-chambers by a series of septa or partitions. The arms of the decapods are furnished with pedunculated suckers, armed with horny rings or hooks. The head is invariably distinct from the body. The eyes are free and movable, and either covered with a fixed, transparent lid or skin, or unprotected and in immediate contact with the water. All the species have either lateral or posterior fins, and the funnel is provided with an internal valve. They live for the most part out at sea, but some—*Sepia*, for example—are met with nearer the shore. The pelagic forms are often found in immense shoals, and are eaten in enormous quantities by many cetaceans and large fishes. When pursued by their enemies, squids have been known to dart out of the sea with such force as to fall upon the deck of a passing vessel. Decapods may be classified in three sections, according to the character of the shell, of which the different types have already been mentioned.

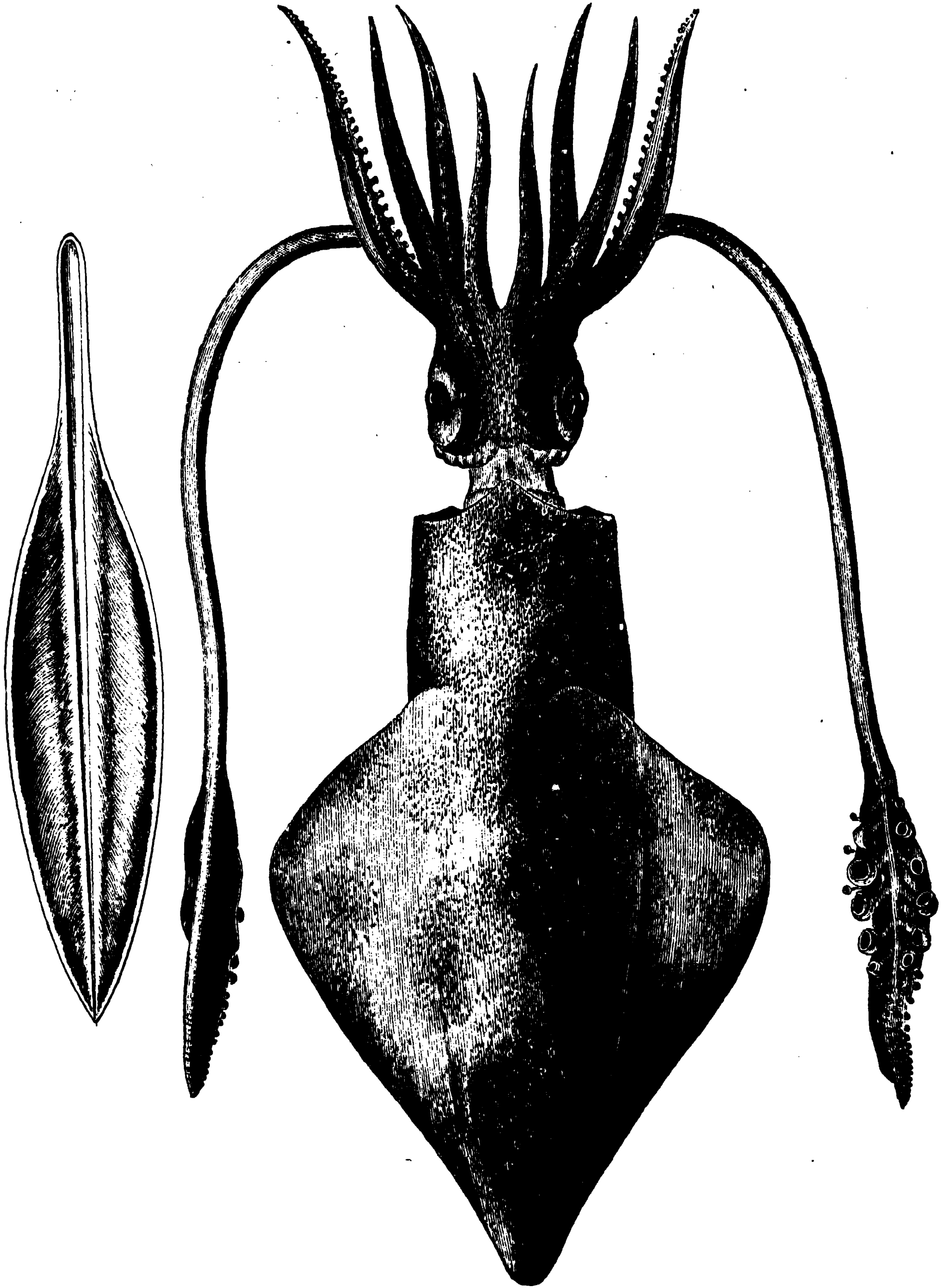
Squids,—Family *Loliginidæ.*

Some of the commonest of the horny pen-bearing decapods are the true squids or calamaries (*Loligo*), which have a more or less elongate body, with very large lateral fins at the posterior end. The eight sessile arms are provided with two rows of suckers with toothed horny rings, and the two tentacular arms are long, slender, and terminate in an expanded club, bearing four rows of suckers. The pen is large, horny, as long as the body of the animal, and placed beneath the skin of the back. It is not in any way attached, so that if the skin be slit open, the shell can be drawn out entire. The common squid (*Loligo vulgaris*) is met with all round the British coasts, and occurs in shoals of greater or less extent in the Mediterranean and Atlantic. The spawn consists of numerous, long, semi-transparent, gelatinous sheaths, radiating from a common centre. Each sheath is about 4 inches in length, and contains numerous ova, and it has been computed that in a single mass of sheaths the deposit of one female contained as many as forty-two thousand perfect young squids. Mr. Lee observes that he has never seen these "sea-mops" attached to anything; and the pelagic habits of the calamaries render it probable that they are left floating on the surface of the sea. They are deposited in May or June. The calamaries are active animals, and always in motion. A second genus of squids (*Ommatostrephes*), frequently regarded as representing a distinct family, differs from *Loligo* in having the body very long, the posterior fins comparatively short, and the pen very narrow. They are gregarious, and frequent the open seas in all latitudes, and are extensively used as bait in the cod-fishery off Newfoundland, and also constitute the principal food of dolphins and the sperm-whale. They are also largely eaten by the albatross and other marine birds. By sailors they are called "sea-arrows" and "flying-squids," on account of the rapidity of their movements and their habit of leaping out of the water. It is said that they frequent the shore in pursuit of the fry of pilchards and other fishes.

The largest of all the Cephalopoda belong to the genus *Architeuthis*, which in general conformation considerably resembles *Ommatostrephes*. Many stories of gigantic cuttle-fishes appear in the works of old writers, and although, in the main, great exaggerations, they are to some extent founded on fact. We are, perhaps, too sceptical to believe in an octopus rising from the sea, and carrying off a three-masted ship. Yet some of the squids are of such enormous size, that we can imagine they constituted the source from which these old tales were derived. In November 1874 a specimen was brought ashore at St. John's, Newfoundland, by some fishermen, who captured it in their herring-nets. It was more or less mutilated in the capture, but the following measurements were taken from the parts preserved. Body 7 feet long, tail-fin 22 inches broad, tentacular arms 24 feet in length, short or sessile arms 6 feet long, some of them being as 10 inches round at the base. Particulars of several other specimens of gigantic squids, varying in total length from 30 to 52 feet, and also taken near Newfoundland, have been recorded; the estimated weight of one of these being 1000 lbs.

On the 24th of April 1875 a large calamary was met with off Boffin Island, on the Irish coast. The crew of a "currah" observed to seaward a large floating mass. They pulled out to it, believing it to be a wreck, but found it was an

enormous cuttle-fish, lying perfectly still, as if basking on the surface of the water. Paddling up, they lopped off one of its arms. The animal immediately set out to



COMMON SQUID, WITH PEN ON THE LEFT (nat. size).

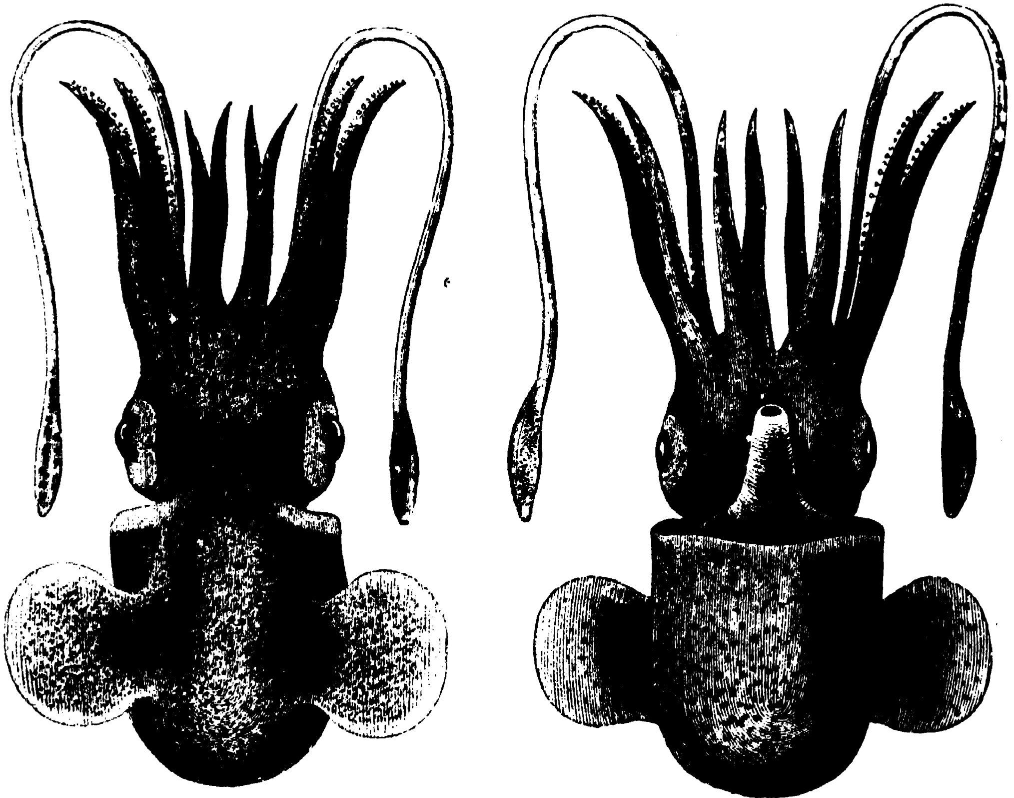
sea, rushing through the water at a tremendous pace. The men gave chase, and, after a hard pull, came up with it, five miles out in the Atlantic, and severed

another of its arms and the head. The shorter arms measured each 8 feet in length, and 15 inches round the base; the tentacular arms are said to have been 30 feet long. A single arm of a large squid, supposed to have been found off the coast of South America, is 9 feet long and 11 inches round the base, and has two rows of suckers, with toothed, horny rings, each row consisting of one hundred and fifty suckers. The largest of these rings is half an inch in diameter, whereas the smallest, near the tapering end of the arm, is only about the size of a pin's head. Judging by other specimens, it is probable that this creature must have had a body 10 or 12 feet in length, with tentacles over 30 feet long.

Some portions of a remarkable gigantic cephalopod were obtained by the Prince of Monaco off the Azores, which were vomited by a harpooned sperm-whale in its death-struggle. The body of this huge squid was covered with scales arranged spirally like those of a pine-cone; and from this character—unique among the Cephalopods—it has been placed in a separate genus *Lepidoteuthis*.

Family SEPIOLIDÆ.

Sepiola is represented by a small decapod not unfrequently found on the British coasts. Mr. Lee observes that "it has the faculty of rapidly changing colour, and,



UPPER AND LOWER VIEWS OF SEPIOLA.

if angered or alarmed, its hue is almost instantaneously altered, from a pale parchment dotted with pink to a deep reddish brown. In its habits this little animal



CEPHALOPODA

differs as much from the *Sepia* as the latter from the octopus. It naturally buries itself up to its eyes in the sand; but as sand is apt to harbour impurities, which in a bowl or tank become corrupt, and generate poisonous sulphuretted hydrogen, the bottom of these receptacles is usually covered with shingle. It is most interesting to notice how, in obeying its burrowing propensity, the *Sepiola* adapts itself to its circumstances and entirely deviates from its customary mode of procedure. To make a sand-pit for its hiding-place, it will direct upon it strong jets of water from its funnel, and thus blow out a cavity in which to seat itself, and allow the disturbed particles to settle over and around it; but, as the pebbles are too heavy to be thus displaced by its blasting apparatus, it removes them, one at a time, by means of its arms, which are large and strong in proportion to its little short body." This same species, *S. rondeletii*, is common throughout the Mediterranean, and is sold in the fish markets of Italy.

Families *ONYCHOTEUTHIDÆ* and *CHIROTEUTHIDÆ*.

The squids belonging to the genus *Onychoteuthis* are very similar to *Loligo*, but are distinguished by having the club of the tentacular arms furnished with strong horny hooks. They are mostly of small size, only a few inches in length; but a very large species (*O. robusta*) was observed off the coast of North-West America, and measured 8 feet in length from the base of the arms to the posterior end of the body. It has since been placed in the allied genus *Ancistroteuthis*. One of the most remarkable of the decapods is the genus *Chiroteuthis*, easily recognisable by the enormous length of the tentacular arms, which are many times the length of the body, so that the animal is enabled to capture its prey at some distance. *C. veranyi* occurs in the Mediterranean, *C. bonplandi* in the Atlantic, and *C. lacertosa* off the east coast of the United States.

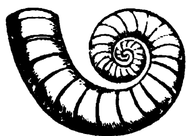
TRUE CUTTLE-FISHES,—Family *SEPIIDÆ*.

In the cuttle-fishes of the genus *Sepia* the body is oval with a fin on each side extending the whole length. The eight sessile arms are furnished with suckers having foot-stalks, and the long tentacular arms are entirely retractile within the head. The dorsal plate, shell, or cuttle-bone, is generally almost as wide as the body, and placed beneath the skin of the back, with the terminal spine posteriorly. This is supposed to protect the hinder parts of the animals, in the frequent collisions they are exposed to in swimming backwards. About sixty species of *Sepia* have already been described, none of very large size, the largest bone being only about a foot and a half in length. A fine specimen of *S. apama* in the British Museum is 17 inches long. They occur in all parts of the world, and three species are recorded from the coasts of Britain. They live near shore, and feed upon fish and crustaceans, which they seize with their rapidly unrolled tentacles. Speaking of the common cuttle-fish (*S. officinalis*), Mr. Lee observes that though flabby and clammy in death, it is a lovely object when alive. Unlike the octopus, but equally rapacious, it loves the daylight and freedom of the open sea. Like the calamaries, the sepia is extensively employed as an article of diet in many

parts of the world. Dried cuttle-fishes are exposed for sale in the bazaars or markets throughout India, and may be seen among the articles of Chinese, Japanese, and Siamese food. The ink of the cuttle-fish was employed as a writing material in very ancient times, its use being mentioned in the works of some of the old Latin writers; the ink-bags of cuttles are still manufactured into sepia by artists' colourmen. Eggs of the common cuttle resemble black pointed grapes, each having a flexible stalk, looking and feeling like indiarubber. They are generally attached to the stems of seaweed. Each capsule contains a single young one.

Family *SPIRULIDÆ.*

Spirula represents the last of the three divisions into which the living decapods have been divided. The shell of the spirula is abundant on the shores of some tropical countries, but the animal is scarcely ever met with. Only a few specimens have been captured, and most of these are in bad condition. The shell is entirely white, pearly within, placed vertically within the posterior part of the body, so that the spire corresponds to the ventral side of the animal. It is a loosely coiled structure, resembling a ram's horn, and is divided into a number of chambers by fine concave partitions, like the shell of nautilus, each one pierced by a slender tube or siphon near the inner curve of the shell. Three species are known, distinguished by differences in the soft-parts, the shells being similar.



Spirula peroni.

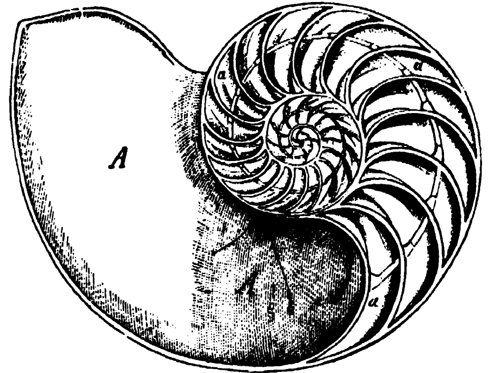
Belemnites.

To the same group as the *Spirula* belongs the extinct family of *Belemnitidæ*, ranging from the Lias to the Chalk, and whose skeletons are commonly known as thunderbolts. They possess a tapering chambered shell, inserted into the summit of a long spear-like guard. Most of the species belong to the typical genus *Belemnites.*

FOUR-GILLED GROUP,—Order TETRABRANCHIATA.
Family *NAUTILIDÆ.*

The nautilus is the sole living representative of this order, and although not so rare as the spirula, the animal of the nautilus is by no means common in collections. It is probably an inhabitant of deepish water, and only likely to be obtained alive by dredging, although a few specimens have been occasionally captured at the surface. The animal is contained within the last compartment (*A*) of a chambered shell, within which it is completely retractile. It does not resemble any of the dibranchiate cephalopods, having numerous small retractile feelers or tentacles, without any suckers, in place of the eight or ten sucker-bearing arms of that order. The beaks are very solid and calcareous, not entirely horny as in the dibranchiates. The eyes are small, and raised on short stalks; the funnel is not a complete tube, being formed of two lobes which fold over one another, but are not joined together. To the posterior end of the body is attached a slender fleshy cord, termed the siphuncle (*a*), which passes through holes in the septa of the shell up the coiled spire. It is enclosed in a horny tube, which is again coated with a calcareous deposit.

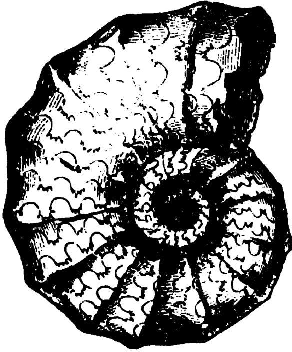
The function of the siphuncle probably is to preserve the vitality of the first formed portion of the shell, which without some such means of preservation would be liable to decay. The animal is somewhat feebly attached to the shell by two large adductor muscles one on each side of the body, which are, as it were, connected by a muscular girdle of the mantle passing round the body from muscle to muscle. The chambered shell is beautifully pearly within, but has an external porcellaneous coating. A full-grown shell has about thirty-six septa, which are relatively equidistant, showing that the growth of the animal is regular and gradual throughout life. The septa give immense strength to the shell, sufficient to resist the pressure of the water at great depths upon the air-chambers between them. These air-chambers undoubtedly serve to buoy up the shell when the animal is swimming or desires to rise to the surface; but the old stories of its filling the cells at pleasure with either air or water, and so rising to the surface or descending to the bottom, are mere fables, and comparable to the legends respecting the sailing of the argonaut. The shells of the male and female are said to present certain slight differences. Very little is known of the habits and economy of the pearly nautilus, but, as already remarked, it is most likely a deep-water animal, as a rule living at depths far beyond the action of storms. It would probably be obtained by dredging or by means of baited traps. A specimen dredged off the Fiji Islands, at a depth of about three hundred and twenty fathoms, was kept alive for some time in a tub of sea water. The mode of growth of the nautilus has been a subject of much discussion, and the way in which the successive air-chambers and septa are formed is not known with certainty. The living forms of *Nautilus* probably belong to three distinct species. *N. pompilius* has a wide distribution in eastern seas, specimens having been obtained in the Indian Ocean (Andaman Islands), at the Moluccas and Java, and in the Pacific at the New Hebrides and Fiji; *N. umbilicatus* is recorded from the Solomon Islands, and New Ireland; and *N. macromphalus* from New Caledonia and the Isle of Pines. The animal of *Nautilus* is used as an article of food among the natives of the New Hebrides, New Caledonia, and Fiji, it being captured by the Fijians in traps baited with boiled crayfish.

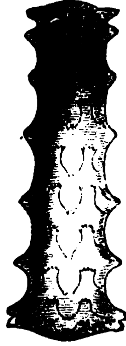


SECTION OF SHELL OF PEARLY NAUTILUS (much reduced).

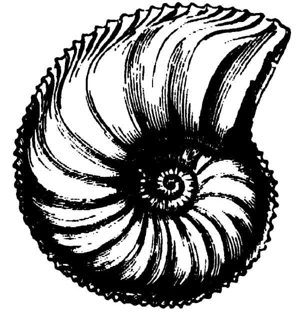
Allied Families. The genus *Nautilus* is of great antiquity, dating from an early epoch in the Palæozoic period, and forms the type of the family *Nautilidæ*, which includes several extinct genera. There are allied extinct families, collectively forming a group characterised by the simple structure of the septa of the shell, such septa having their concavities directed towards its aperture. Among these, the *Orthoceratidæ*, as typified by the Palæozoic genus *Orthoceras*, may be characterised as unrolled nautili, the shell—which sometimes reaches an immense length—forming a long cone.

Another well-marked group is that of the Ammonoidea, represented by the goniatites of the Palæozoic, and the various types of ammonites of the Secondary rocks, as well as by the turrilites of the Chalk. In all these the edges of the sutures, where they join the shell, are more or less complexly angulated or frilled, the complexity being very great in the ammonites, but a simpler type obtaining in the goniatites.





A CERATITE (*Ceratites nodosus*).



AN AMMONITE (*Cardioceras cordatum*).

Whereas in the two latter the shell is coiled in a flat spiral, in the turrilites it forms a cone, while in the hamites and baculites of the Chalk it is either straight or partially coiled. In the ceratites and ammonites (which include *Ceratites*, *Cardioceras*, and many other genera) the mouth of the body-chamber of the shell was closed by an operculum, which often consists of two pieces meeting in the middle line, and the whole being heart-shaped. In other forms the operculum was single. Mr. Cooke observes that "some authorities hold that the members of this suborder belong to the Dibranchiata, on the ground that the protoconch resembles that of *Spirula* rather than that of the Nautiloidea. Others again regard the Ammonoidea as a third and distinct order of Cephalopoda. Their distribution extends from the Silurian to (possibly) the early Tertiary. No trace has ever been found of an ink-sac, mandible, or hooks on the arms; and the shell was undoubtedly external."

EDGAR A. SMITH.

CHAPTER X.

MOLLUSCS,—*continued.*

THE GASTROPODS,—Class **Gastropoda.**

THE Gastropods constitute by far the largest division of the Mollusca, and include among their number forms which bear no external resemblance whatever to one another. Some are free-swimming animals, living far from land, out on the open seas; others occur in shallow water, or between tide-marks; while others are dwellers on the land, or frequent rivers and lakes. Some have internal, others external shells, whilst many have no testaceous structure of any description. Snails, whelks, and periwinkles are typical forms of Gastropods, and the more aberrant types are represented by the Nucleobranchs, Heteropods, and Pteropods. The typical Gastropods are all crawlers, moving like a slug or snail by a continual expansion and contraction of the muscular foot. Some breathe by means of gills, others by a lung, while certain forms are provided with both modes of respiration. They are generally furnished with a spiral shell when adult. They are mostly unsymmetrical animals, lying spirally coiled within the shell; this want of symmetry being particularly manifested in the breathing-organ. In many marine forms there is only a single gill, but in a few genera—*Fissurella* for example—the gills are paired. There is always a more or less distinct head, bearing one or two pairs of tentacles, and there are generally a pair of eyes situated at the base or end of the tentacles; or raised upon short stalks. The mouth is usually provided with one or more jaws, and the lingual ribbon, or radula, within the mouth, varies greatly in its armature, and plays an important part in the various schemes of classification which have been proposed. While enormously developed in some groups, such as the limpets, in a few it is entirely wanting. It consists of a thin chitinous membrane, the surface of which is beset with a multitude of so-called teeth, symmetrically arranged in transverse or oblique series. The teeth are siliceous, insoluble in acid, and capable of rasping away hard substances. With it the whelk and other carnivorous forms bore through the shells of bivalves, and the limpet eats away the calcareous nullipore. Not only is the form of the teeth extremely variable, but their number varies enormously in different groups. In an *Eolis*, one of the Nudibranchs, there are but sixteen teeth; in a *Doris*, belonging to the same group, there are as many as six thousand, whilst in a large species of *Helix* the number has been estimated at nearly forty thousand. The shells of Gastropods are usually spirally coiled as in the snail, but sometimes they are tubular or conical, like that of the limpet. The forms of spiral shells are innumerable and very unlike; some being globose, with simple rounded aperture, while others are narrow and long, with prolonged spires, and the mouth produced into a long anterior beak.

The colour and ornamentation of the surface are also as varied as the shape. Nearly all spiral shells are dextral, but a few genera (*Physa* and *Lanistes*) are normally sinistral; while in other groups (*Achatinella, Amphidromus*, etc.) some of the species are indifferently dextral or sinistral. A large proportion of the Gastropods entirely or partly close the aperture of their shells with what is termed an operculum. This is sometimes horny, like that of the common periwinkle, or it may be solid and calcareous as in the *Turbinidæ*. The different forms assumed by this structure have afforded characters for separating many groups generically. The operculum is generally attached to the hinder part of the foot, so that when the animal withdraws within the shell—it more or less closes the aperture, and thus protects itself. In many species the operculum is very small, and would not serve as a defensive weapon, whilst in others it is altogether wanting. Gastropods may be classified in three principal divisions or orders, namely, the Pulmonata, Opisthobranchia, and Prosobranchia.

THE LUNG-BREATHING GROUP,—Order PULMONATA.

The order Pulmonata comprises all the true land-snails,—excepting such as are provided with an operculum,—the inoperculated forms of fresh-water snails, and the family of the *Auriculidæ*. The latter forms a considerable group, the members of which are chiefly met with in salt or brackish marshes, although there are three or four genera which are strictly littoral in their habits. All the Pulmonata are provided with a breathing-cavity, which is not freely open as in the terrestrial and fresh-water Prosobranchs, but has only a small opening which is contractile so as to exclude the water in the aquatic species, and the hot air during the heat of summer in the terrestrial forms. This lung-opening is seen on the right side of most snails and slugs a little behind the head, and at once closes up if the animal be molested. With a few exceptions, the fresh-water Pulmonates rise to the surface to breathe, and are suffocated if prevented from obtaining the requisite supply of air. They can be drowned just as easily as a slug or snail beneath the water, but naturally the process would be longer in these animals, in which the breathing is habitually much slower. In the case of *Ancylus*, however, this could not be effected; and a fresh-water pulmonate, *Physa lamellata*, from Madagascar, possesses a well-formed gill.

The Pulmonata may be separated into two main divisions, according to the position of the eyes. In the Stylommatophora, represented by slugs and snails, these are situated at the tip of retractile tentacles, whereas in the Basommatophora they are placed at the base of the tentacles, which are only contractile and not retractile within themselves as in the former section. The Stylommatophora are mostly more or less slimy, and leave a mucous track behind when crawling. Although they are chiefly vegetarians, some are not only carnivorous, but even cannibals at times. They are found in all parts of the globe, from the Arctic regions to the Tropics, but are most abundant in those countries where there is plenty of lime and moisture. The sexes are not distinct but united in each individual. The eggs of terrestrial molluscs are far less numerous than those of the marine forms, and are deposited separately. They are mostly round or egg-

shaped, and are generally laid in the earth under stones or leaves, and there left to hatch by themselves. On emerging from the egg, the animals are practically the same as the parent, but the form of the shell, when present, generally alters very much in the course of growth.

SHELLED SLUGS,—Family *TESTACELLIDÆ*.

The shelled slugs, or *Testacellidæ*, have no jaws, but are armed with a tongue bearing oblique series of long, narrow, pointed teeth, indicative of their carnivorous habits. While some members of the family are without any external shell, the majority are provided with shells capable of entirely covering the animals, but a few have only very small ear-shaped shells attached to the upper surface of the hinder end of the foot. To the latter group belongs *Testacella*, the typical form of the family. This genus includes elongated slug-like animals, with the breathing orifice at the posterior end of the body, which is capable of great extension and contraction. They prey upon earthworms, which are pursued in their burrows under ground. In a recent account of the habits of *T. scutulum*, Mr. Webb observes that it usually seized the anterior end of the worm, and gradually swallowed it; but occasionally the middle was seized, in which case the worm forced itself away. During cold northerly and easterly winds these creatures enclose their bodies in a kind of cocoon, like that of the silk-worms, which is secreted from the skin, and often mixed with earthy and extraneous particles. These slugs deposit a few calcareous eggs, which in form are as symmetrical as those of a bird, and large in proportion to the size of the animal. It is doubtful whether this genus is truly indigenous to Great Britain, or merely an introduction of comparatively modern times. The only other parts of the world besides Europe where *Testacella* occurs, are Algeria and the Azores, Madeira, and Canary Islands.


SHELL-BEARING SLUG, *Testacella haliotidea* (nat. size).

Glandina forms an extensive genus of *Testacellidæ*, chiefly restricted to the central parts of America; one species, however, being European. Like *Testacella*, these are very voracious, and even attack their own species. *Daudebardia* is another slug-like genus of this family, carrying a small shell upon the tail. They occur in Southern and Eastern Europe and Western Asia, and in New Zealand are closely represented by *Schizoglossa*, the external aspect of which is very similar. The allied *Streptaxis* is remarkable for the peculiar obliquity of the last or body-whorl in relation to the spire in most of the species. The first-formed part of the shell is regular in its growth, like an ordinary garden snail-shell, but suddenly the growth becomes irregular, giving the shells a very oblique and distorted appearance. The object of this deviation from the ordinary form of growth is not apparent, but

it doubtless serves some special purpose. Nearly all the species of this genus are of a whitish colour, polished or obliquely striated. They chiefly occur in South America, Tropical Africa, Southern Asia, and certain islands in the Indian Ocean.

TRUE SLUGS,—Family *LIMACIDÆ*.

This family contains many genera of naked slugs, and several either partly or wholly protected by well-developed shells; the hinder end of the foot in some forms terminating in a conspicuous mucus or slime-pore. The typical slugs are mostly elongate animals, capable of great contraction, and always pointed or attenuated behind. The mantle forms a sort of shield, placed over the fore-part of the back, and beneath this is situated a small calcareous plate, representing the shell. These plates occur fossil in Eocene beds. The respiratory orifice is seen on the right side of the shield, but rather far back. The head is prominent in front, bearing two pairs of retractile tentacles, of which the upper are the longest, and furnished with eyes at the bulbous tips. The mouth is provided with a horny upper jaw, which is smooth, with the cutting edge produced into a sort of beak in the middle. The radula has numerous transverse series of horizontal or slightly oblique teeth, of which the central tooth is three-pronged, the laterals about the same height as the central one, while the marginal teeth are narrow and acute. The body is united to the foot, and is more or less wrinkled; the wrinkles being most conspicuous when the slug is contracted, and to some extent characteristic of the different species. The *Limacidæ* live in damp places, out of doors, or in cellars, and hide away during the daytime under stones, dead leaves, or in fact in any place where it is dark and moist. They feed chiefly on decaying vegetation, but some are more or less carnivorous. Certain species are great pests in gardens. *Limax agrestis*, the "milky slug,"—so called from the opaque white colour of its mucus,—is a very common species in England; it is very fond of strawberries, and is also said to feed upon earthworms. These slugs increase in numbers rapidly, and are said to produce several families in the course of a summer; a pair having been known to lay nearly eight hundred eggs. Some species of *Limax* are capable of lowering themselves to the ground from the branch of a tree by secreting a slimy thread. The largest species occuring in Britain is *L. maximus*, which has a very wide range on the Continent, and sometimes exceeds 6 inches in length. One may often notice numbers of a minute white parasitic mite (*Philodromus*) running about the body of this slug, and it is said also to live in the respiratory cavity, but does not appear to cause any annoyance or injury to its host.



GLASS-SNAIL (*Vitrina*) AND AMBER-SNAIL (*Succinea*). (Nat. size.)

In the genus *Vitrina* the animal is provided with a fragile, external, horny shell, not sufficiently large to receive it entirely, when contracted. The shells are all very much alike, and precisely similar to those of *Helicarion*, another genus of *Limacidæ*, which, however, is distinguished by having the foot truncated obliquely behind, and furnished with

a large terminal mucus-pore, and there are other anatomical differences. The single British species is here figured. Unlike *Vitrina*, the snails known as *Zonites* and *Vitrea*, together with some allied genera, are wholly retractile within their shells. There are several British species of *Vitrea*, and their identification from the shells alone is a matter of considerable difficulty. In their habits they closely resemble *Vitrina*, being carnivorous rather than vegetarian. They greedily devour any kind of animal food, even in a putrid condition, and are also said to prey upon some of the larger snails. They are generally found hidden away under stones, dead leaves, or moss, and some of them emit a strong smell, like garlic, which is perceivable at a distance of some feet.

THE SNAIL TRIBE,—Family *HELICIDÆ*.

Like the *Limacidæ*, this family includes forms with or without an external shell. In nearly all the genera the cutting-jaw of the animal is more or less ridged, and not smooth as in *Limax*. The principal distinguishing character occurs in the structure of the radula, which is composed of many rows of very numerous similar square-based teeth, arranged so regularly as to have a tesselated appearance. It is very broad, and the number of teeth in a row, although usually less, is sometimes as great or even greater than the number of rows. This family includes an enormous number of species from all parts of the globe. These occur everywhere and in all climates; in dense forests, on the top of grassy downs, in valleys, fields, lanes, in the arid desert, and at an elevation of some ten thousand feet both in the Old and New World.

To an ordinary observer, the members of the genus *Arion* (sometimes placed in a separate family, *Arionidæ*) are merely slugs. Externally the resemblance is



BLACK SLUG, *Arion empiricorum* (nat. size).

very close, but the different position of the respiratory orifice, and the presence of a mucus-pore at the end of the foot, readily separates this genus from *Limax*. Besides these differences, the radula is of a different type. In *Limax* the breathing-hole is situated near the hinder end of the shield, whereas in *Arion* it is much

further forward. In the present genus there is no internal shield-like shell, as in *Limax*, but this is represented by a few unequal calcareous particles beneath the mantle. Nine species of this genus are said to occur in Britain, and of these the large *A. empiricorum* is the commonest and best known. It is sometimes intensely black, but it may be brown, red, yellow, greenish, or even white. This great variation in colour is unaccountable, for black and red specimens occur in the same districts where the natural surroundings are practically the same. The edge of the foot, when crawling, displays a yellowish or orange border crossed by closely-set black lines. This species usually feed on vegetable substances, but it has occasionally been known to devour earthworms. It ranges over a considerable part of Europe, and has been recorded from Siberia, Corsica, and as far as Madeira.

The genus *Helix* includes the true snails of the type represented by the garden-snail (*H. aspersa*), and the edible or vine-snail (*H. pomatia*), as it has been variously named. The animal is completely retractile within its shell, and the body distinct from the foot, and well protected by the spiral shell. The breathing-orifice is on the right side beneath the margin of the aperture of the shell. The genus *Helix*, as understood at the present time, is much more limited than it was some years ago, and the tendency of conchologists is to propose still further limitations. The necessity of dividing an enormous genus like *Helix* containing thousands of species, is universally recognised, but the danger arises of carrying this sectionising too far. Many of the divisions are partly founded upon geographical considerations. The form of the shell in *Helix* is extremely variable, as a glance at any collection will show. Some are sharply conical, others globular, or flat and acutely keeled at the circumference; and the variety of colour is endless, and changeable in specimens of the same species. The British *H. nemoralis* and *H. hortensis* are striking examples; and *H. picta*, a beautiful Cuban shell, is another remarkable instance. Not only does the ground-colour offer many variations, but the colour and disposition of the spiral lines or bands which adorn the surface are equally variable. The twenty-five species of *Helix* which occur in Britain are insignificant in comparison with their exotic relatives, although large enough to do a considerable amount of damage in the garden. The finest is the *H. pomatia*, popularly known as the apple-snail, but this name, as pointed out by various writers, although appropriate as regards its shape, was not derived from the Latin *pomum*, an apple, but from the Greek *poma*, signifying a lid or operculum. When winter is approaching, the animal secretes a diaphragm or covering to the aperture of the shell, a false operculum, to keep out the cold and wet when hibernating under ground. It is composed of slime and calcareous matter, but is not pierced with a minute breathing-hole, as is the case in some other species, although probably sufficiently porous to permit of whatever change of air may be necessary during the winter sleep. The eggs of *H. pomatia* are deposited in June in holes in the ground, formed by the snail itself. They are about the size of a small pea, and much resemble in colour and consistency the berries of the mistletoe. Only a day or two is occupied in the production of sixty to eighty eggs, and these are then covered up with earth and the ground so levelled that the place, or egg-nest, is difficult to discover. The length of time before hatching varies according to locality and the state of the temperature. It

may be from about twenty to forty days before the young snail eats through the skin or shell of the egg, and this it is said to entirely consume. Although *H. pomatia* is commonly styled the edible snail, it should be remembered that other species are also considered a delicacy; *H. aspersa, H. naticoides*, and *H. vermiculata* being commonly eaten in parts of Italy and Sicily; while in Naples, *H. ligata* and *H. lucorum* are also to be seen for sale. *H. mazzullii*, which is collected near Palermo, possesses the power of boring into the rock; this being probably effected by means of the radula. The supposed object of these excavations is to secure a place of refuge during the period of excessive heat, and also to obtain a supply of lime for the formation of the shell. The Philippine Islands are the home of a beautiful genus of snails (*Helicostyla*), many of which are clothed with a peculiar periostracum, which, when wetted, becomes more or less transparent, disclosing the colour of the shell beneath. Two or three of the species are of a bluish tint, a colour not found among other land-shells.

The important genus *Bulimus* (now abolished in favour of *Strophocheilus*) formerly contained a large number of species from all parts of the world, but is now limited to a comparatively few forms occurring in South America; *S. oblongus* being one of the commonest and best known species. Another, *S. maximus*, is sometimes as much as 6 inches in length. The majority of the other species, originally classed in *Bulimus*, are now located in *Bulimulus* and its sections, or in *Buliminus*. These genera are distinguished by differences of the jaw and radula.

Other Families.

There are several other families of land-shells, which can only be briefly referred to. The *Cylindrellidæ* are very elongate, many-whorled shells, which occur principally in the West Indies and South America; many of them being remarkable for their slender forms and exquisite sculpture. A peculiarity of *Cylindrella* consists in the shell being almost invariably truncated, that is, the upper whorls are broken off when the animal reaches maturity. This may be done to lighten the shell, which otherwise would be too long for the mollusc to carry erect. The *Pupidæ* comprises a number of forms which are conchologically very dissimilar. The typical *Pupa* includes minute creatures, and appears to be found in all parts of the globe, but especially in temperate and mountainous regions. They are gregarious and live in moss, under stones, in the crevices of old walls, or among the roots of grass and other plants. Most of the species have what are called "teeth" within the aperture of the shell, and these in some species are so numerous as to almost close the opening, and thus make it, one would suppose, a matter of some difficulty for the animal to squeeze through them when emerging from its shell. *Vertigo* is a genus similar to *Pupa* as regards the shell, but separable on account of the animal having only one pair of tentacles, the lower pair being entirely wanting. The shells, according to the species, are dextral or sinistral. *Clausilia* is remarkable for the large number of species, the general similarity in the form of the slender shell, and the peculiar process within it, which serves as a door to shut in the animal when retracted. The shells are almost invariably reversed, and furnished with two or three folds or plicæ within the mouth, and other lamellæ still further within, which can only be detected by the transparency of the shell



Clausilia.

itself. About a thousand species have been described. They are most numerous in Europe and Eastern Asia, only a very few species being known from South America. *Achatina* is one of those genera the scope of which has been greatly altered since it was first founded by Lamarck. In those days any land-shell with a notch or truncation in the pillar-lip of the aperture was considered an *Achatina*. It is, however, now reserved for a group of large snails which are only met with in Africa, Madagascar, and a few other adjacent islands. They have fine handsome shells, vividly painted with more or less wavy stripes, and covered with a thin periostracum. *A. variegata*, in the tropical forests of West Africa, is sometimes 7½ inches in length, and the largest of all the living land-shells.

The members of the extensive family *Achatinellidæ* are inhabitants of the Sandwich Islands, and occur in no other part of the globe; the species being all small, and many of them both dextral and sinistral. Some are found on trees



AGATE-SNAIL (*Achatina fulica*).

and shrubs, whilst others are always met with on the ground. Mr. Barnacle has given an interesting account of the production of musical sounds by these little land-snails. He described the sound as resembling that of hundreds of Æolian harps, and believed it was produced by the friction of the shells against the bark of the trees upon which the snails were crawling.

The amber-snails (*Succineidæ*) bear a strong family likeness to one another. The shells are all very fragile, oblong, yellowish, or reddish, with a more or less exserted spire and a very large body-whorl. They are found in damp situations, and have even been observed crawling beneath the water, upon which they can float in a reversed position. They are vegetarian in their diet, and deposit their eggs on the stems and leaves of aquatic plants, and also upon stones or other substances near the water's edge. Species of *Succinea* occur in most parts of the world, being met with in such remote localities as Greenland, Patagonia, India, Japan, Australia, and the South Sea Islands. The species

figured on page 344 is found all over Europe, and ranges even as far as Afghanistan. The character of the radula is shown in the figure on the next page.

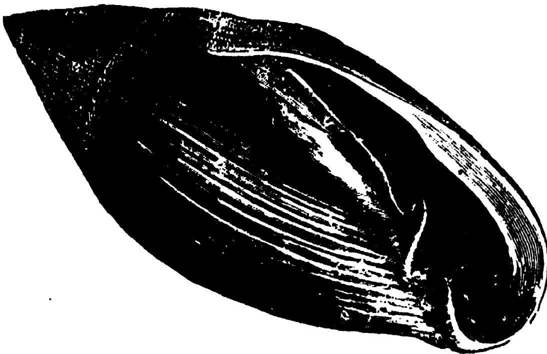
The family *Oncidiidæ* includes about fifty shell-less air-breathing molluscs, somewhat slug-like in general appearance, but provided with a thick mantle covering the whole dorsal region. This is frequently more or less tubercular, some of the tubercles being furnished with eyes which, simple as they are in structure, are identical in type with those of the Vertebrata. These snails live on the seashore or in brackish marshes, eating nothing but sand, but, of course, only digesting the nutritious organic particles contained in it. Professor Semper has given an account of their habits, and how they are pursued by certain fishes (*Periophthalmus*), which come ashore after them. One species, *O. celticum*, is found in Cornwall and South Devon, others occur in America and the Pacific.

Basommatophora. The numerous forms belonging to this group, comprising the rest of the Pulmonata, differ from those already indicated, in having the eyes situated at the base of the tentacles, as in the marine whelks and periwinkles, instead of at the tips. An external shell is always present, and capable of containing the entire animal. The members of the family *Auriculidæ* mostly inhabit salt or brackish marshes, and were formerly regarded as marine molluscs. The shells generally are rather solid, of different forms, but usually with narrow apertures, more or less contracted by teeth. The internal septa between the whorls of the spire are often absorbed or dissolved, excepting that between the last and penultimate volutions. Some species of the typical *Auricula* have large heavy shells, and are met with in mudbanks and in swamps, in the Indian Archipelago. Those belonging to *Pythia* have oval, compressed shells, with toothed apertures, and occur in great numbers in most places in woods near the sea, are wholly terrestrial in their habits, and feed on decayed vegetation. One member of this family (*Carychium minimum*) is found in Great Britain, and on the Continent. It is an extremely small shell, less than the tenth of an inch in length, transparent, glossy, having three teeth-like projections within the aperture. It hides away at the roots of grass, among moss, dead leaves, or under stones or dead wood, in damp situations.

Earlet Shells. Auriculidæ.

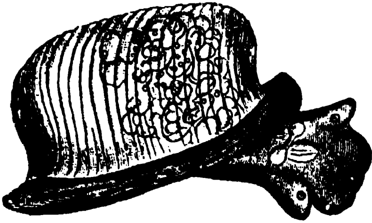


Pythia scarabæus (nat. size).



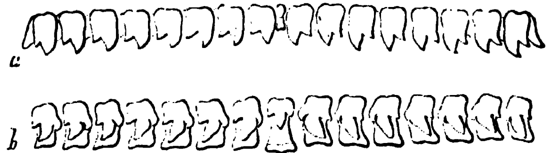
EARLET SHELL, *Auricula judæ* (nat. size).

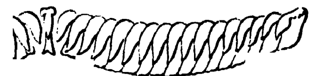
Pond-Snails, etc. The three families *Limnæidæ*, *Physidæ*, and *Chilinidæ* form a second group of the Pulmonates with sessile eyes, all being inhabitants of fresh water, but rising occasionally to the surface to renew the supply of air. They are mostly herbivorous, but some kinds of *Limnæa* and *Physa* are said to become carnivorous occasionally. In the first family the members of the genus *Ancylus* are popularly known as fresh-water limpets, on account of the resemblance in form of their shells to the true limpets. They have all small thin shells, with the apex somewhat posterior, but generally inclining a little to the right or left. They are found on all four continents, as well as in Australia, New Zealand, the West Indies, and other islands; two species being British. *A. fluviatilis* occurs generally on stones, but occasionally on plants in shallow streams, and running brooks, whereas *A. lacustris* invariably adheres to the stems and leaves of plants in ponds, lakes, and canals. On account of this difference of habit, and also for various anatomical reasons, the latter species has been placed in a separate section (*Velletia*). The illustration represents the embryonic stage of this species just prior to its quitting the ovum.



EMBRYO OF RIVER-LIMPET (*Ancylus*).

The fresh-water snails belonging to the genus *Limnæa* have thin horny shells, with more or less sharp spires, and are usually dextral, but certain forms occurring in the Sandwich Islands, Australia, and probably other neighbouring localities, are constantly sinistral, so that it is impossible to separate them from the genus *Physa* by the shells only. An examination of the animals, however, at once determines their proper position. In *Limnæa* the two tentacles are compressed and triangular, with the eyes at their inner base. In *Physa* they are cylindrical. The jaw and radula are also different in the two genera. The species of *Limnæa* frequent shallow and still waters, in most parts of the globe, often swimming at the surface of the water in an inverted position. They are prolific and gregarious, and the eggs are enclosed in transparent gelatinous capsules, and deposited in continuous series, and attached to submerged stones as well as to the stems and leaves of aquatic plants. *L. stagnalis*, which is common in ponds, marshes, and slow rivers, is the largest species, and six other species occur in Britain. The other figured forms illustrate the great variation which occurs in the relative length of the spire and aperture. In one of these (*L. truncatula*) the liver-fluke, so destructive to sheep, passes one stage of its existence.





ROW OF TEETH OF RADULA OF—*a*, *Limnæa stagnalis*; *b*, *Ancylus fluviatilis*; *c*, *Succinea putris*. (Greatly magnified.)

The animals of the genus *Planorbis* are small, and have the vital organs on the left side. The tentacles are slender as in *Physa*, but there are no lateral mantle-lobes. The shells are all very similar, being sinistrally and spirally coiled

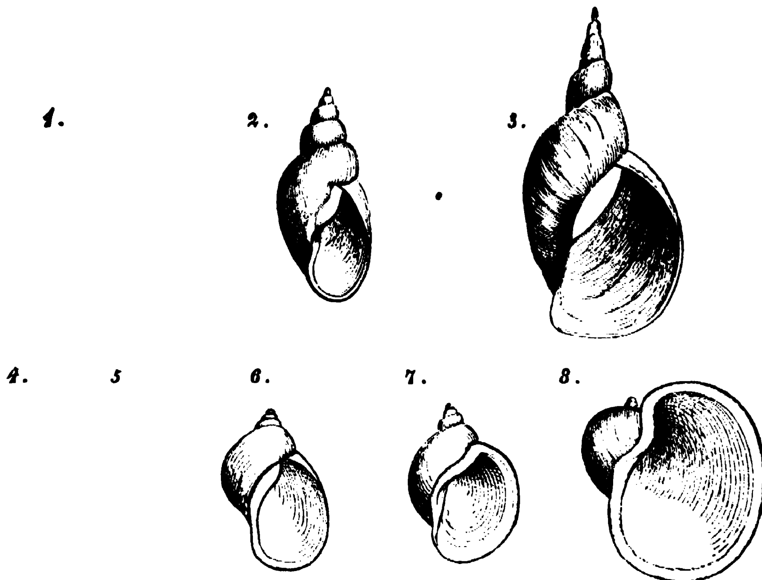
up like a rope, in the same plane. They frequent stagnant pools and ditches, or slowly running water, in all parts of the world. The well-known *P. corneus* is not only by far the largest of the eleven British species, but also larger than any



COMMON POND-SNAIL (*Limnæa*).

other known form, although some of the South American types approximate closely. When disturbed, it emits a purple-coloured fluid, probably as a means of defence.

In *Physa* the animal is always sinistral, having the respiratory and genital orifices on the left side. The tentacles are cylindrical, and the eyes are at their



VARIOUS FORMS OF THE GENUS LIMNÆA.
1, *Limnæa glabra*; 2, *L. palustris*; 3, *L. stagnalis*; 4, *L. truncatula*; 5, *L. peregra*; 6, *L. vulgaris*; 7, *L. ovata*; 8, *L. auricularia*.

inner base, as in *Limnæa*. The mantle is furnished on each side with more or less elongate lobes, which, when the mollusc is crawling, are folded back upon the exterior of the shell. In their habits these snails resemble the preceding genus, and they are almost cosmopolitan in their distribution. *Physopsis*, a Central and South

African form, has a reversed shell like *Physa*, but is distinguished by having a tooth or fold on the columellar margin of the aperture. In *Chilina* the shell is dextral, like that of *Limnœa*, but differs in being covered with a periostracum, and exhibiting reddish wavy colour markings. The columella is thickened and furnished with one or more folds or plaits. They are found only in clear running streams of South America.



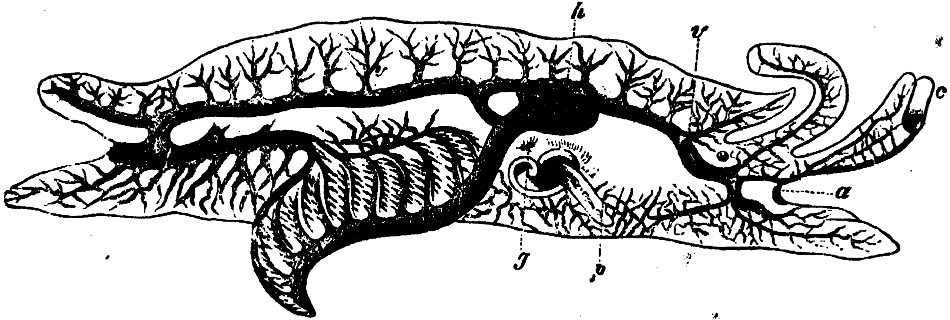
RAMSHORN SNAIL (*Planorbis corneus*).

The curious pulmonate known as *Amphibola* somewhat resembles a periwinkle in form. It lives between tide-marks in brackish or salt water, on mud-flats at the mouths of rivers in New Zealand, and is used as food by the natives. It is abundant in some places, and is a sluggish creature, subsisting upon the vegetable matter contained in the mud, large quantities of which it passes through the alimentary canal. Professor Hutton says that it will live for a week or ten days in fresh water, and more than a fortnight in salt water, without being exposed to the air. The breathing-orifice is situated on the right side of the neck, and the radula shows some affinity to that of *Physa*. The shell is solid, globular, with a short spire and an oval aperture. The animal is furnished with a thin horny subspiral operculum.

The Hind-Gilled Group,—Order Opisthobranchiata.

The Opisthobranchs form the second of the three main divisions of the gastropods, and are all marine forms, having the sexes united in each individual, and breathing chiefly by gills or branchiæ. This character at once separates them from the Pulmonata, and the different positions of the branchiæ, and their hermaphrodite nature, serve to distinguish them from the Prosobranchia, the third and last main branch of the Gastropods. In the Opisthobranchs the branchial veins as

well as the auricle are placed behind the ventricle of the heart, but in the Prosobranchs the branchial system is anterior to the heart. The majority of the molluscs included in this order are unprovided with a shell in the adult state; but there are some exceptions, such as the shell-bearing Pteropods, and many of the Tectibranchs. They are generally furnished with a pair of tentacles and labial palpi, or an expansion of the skin like the veil of the larval form. To comprehend the character of the internal organisation, the above illustration should be consulted. It represents a longitudinal section of the animal; *p* is the foot; *a*, the mouth, covered above with the veil-like expansion, over which are the tentacles *c*; *v* shows the branchial veins carrying the blood to the gills, from which it flows into the heart. This position is the opposite of that which characterises the Prosobranchs. Another anatomical peculiarity, which may here be referred to, is the direct communication of the system of blood-vessels with the surrounding medium—a character common to most other molluscs, and on which depends the



CIRCULATION IN *Pleurobranchus aurantiacus.*

changeable external appearance of the individual. In the illustration of *Pleurobranchus*, as above, *g* indicates the opening of a duct which conveys water direct to the blood, and through which the blood-vessels permeating the back and foot, like the holes in a sponge, can be filled or emptied at the will of the animal. Although this, in the main, is the principle of the circulation in most Opisthobranchs, one branch of the order possesses no special breathing-organ, respiration being effected through the naked skin of the body. The Opisthobranchia may be divided into three principal suborders, namely, Nudibranchiata, Tectibranchiata, and Pteropoda.

NAKED-GILLED SUBGROUP,—Suborder **Nudibranchiata.**

The naked-gilled Gastropods constitute a large assemblage of extremely beautiful molluscs, of remarkable shape, and often brilliant coloration. The distinguishing characteristic of the typical forms consists in the breathing-organs being exposed on the back of the animal, and not protected by the mantle. Other groups, however, are classed within this suborder, in which either the position or character of the respiratory organs is different. The gills may be situated on each side of the body between the back and the foot, or respiration be effected by the ciliated surface of the body. For these and other reasons the Nudibranchs

have been arranged in four groups, Anthobranchiata, Inferobranchiata, Polybranchiata, and Pellibranchiata. A fifth group, Parasita, has also been proposed for a very curious mollusc (*Entoconcha*), which lives parasitic within an echinoderm (*Synapta*). Nudibranchs are found in all parts of the world, and are most abundant in depths where seaweeds and corallines flourish, although they are also found at low-water or even between tide-marks. A few species have been dredged at great depths. Some even pass their life in the open sea, attached to floating seaweeds, or swim about freely like Pteropods or Heteropods.

Anthobranchiata. The animals belonging to this group are characterised by their symmetrical form, and the position of the vent. This is placed upon the posterior or central part of the back and surrounded by the branching gills, which are more or less contractile. The body is protected above by a large dorsal shield of a spongy texture, and made more or less rigid by calcareous spicules which are embedded in it. The tentacles are dorsal, and retractile through holes



Acanthodoris pilosa (magnified).

in the mantle some distance from the anterior extremity of the body. They are smooth at the base, but lamellated towards the tip. The eyes are minute and situated in the skin behind the tentacles.

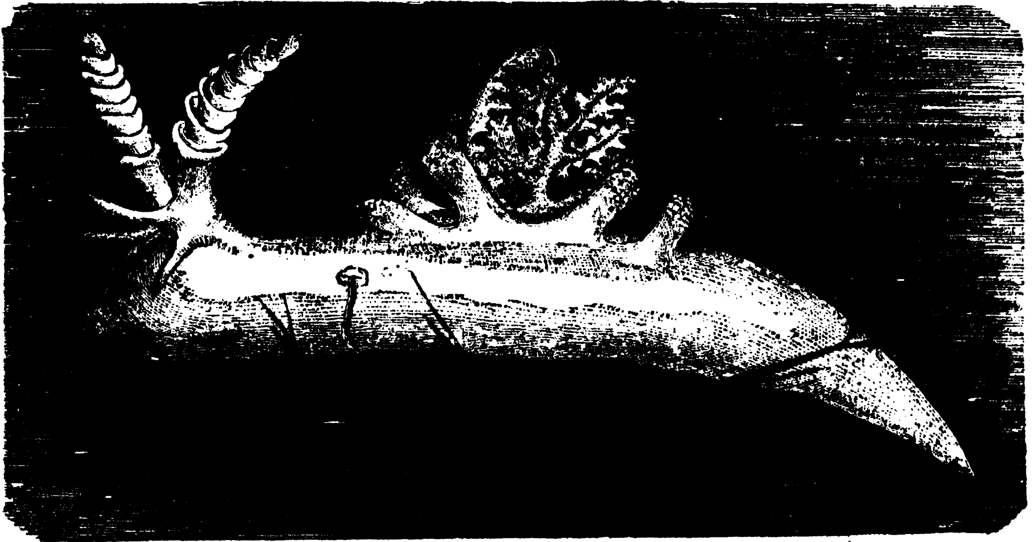
Doris Tribe. A large number of species from all parts of the world, at one time considered forms of the old genus *Doris*, are now placed in the distinct group *Doridopsidæ*, on account of differences in the oral organs. The general aspect of the animals of this family is the same as that of *Doris*, the gills being arranged in a circle around the vent on the posterior part of the back. The buccal mass or eating apparatus is small, without jaws or radula, and organised for suction. The extensive family *Dorididæ*, contains a considerable number of genera and subgenera, characterised by differences in the branchiæ, the relative proportion of the mantle in regard to the foot, and variations in the radula and jaws The general aspect of the genus *Doris* is represented by the figure here given of *Acanthodoris pilosa*. The species are very numerous, and some of them are amongst the largest of all Nudibranchs. They are world-wide in their distribution, over twenty species occurring in British Seas. When living, they are most beautiful objects, and must be studied in that state, for when dead and immersed in spirit, they so contract that their natural form can only be guessed.

and all the beautiful and varied colours disappear. The spawn of *Doris* and other Nudibranchs is deposited in the shape of a gelatinous band, always arranged in a more or less spiral form, and fastened by one of its edges to corallines or the under sides of stones. The ova are minute and very numerous, amounting in some species to several thousands. Before the period of exclusion, the young may be seen revolving on their own axis, by means of vibratile cilia, and on escaping from the egg they swim about freely in the water by the same means. The larva is extremely minute, and has more the appearance of a wheel-animacule than a mollusc. It is enclosed in a transparent, calcareous, nautiloid shell, with an operculum. Its structure is very simple, showing no signs of the external organs that distinguish the future adult; the principal portion visible outside the shell being composed of two flat discs or lobes, fringed with long cilia, by the motion of which it swims freely through the water. These are often withdrawn into the shell, and the operculum is closed upon them when the animal is at rest. *Doris mabilla*, a fine handsome species, having a wide distribution in the Indian and Pacific Ocean, is fully 4 inches long and 2 to 3 in width. It has been obtained at the Seychelles, Andaman, and Samoa Islands. *Bathydoris abyssorum* was dredged in the mid-Pacific, at a depth of two thousand four hundred and twenty-five fathoms. It is a large animal, about 5 inches in length, of a nearly spherical form, subgelatinous, subpellucid, and greenish white, with a dark purple foot. The branchiæ are non-retractile, and disposed in six groups. It forms a remarkable connecting link between the *Tritoniidæ* and the *Dorididæ*. In the genus *Hexabranchus* the gills are arranged in a circle round the vent, and are composed of six separate plumes, each of which is retractile within a special cavity of its own, and not within a common cavity as in *Doris*. The species are not numerous, and have only been met with in warm seas, such as the Red Sea, and Indian and Pacific Oceans. *H. sandwichensis*, a handsome species of a pale crimson tint occurring at the Sandwich Islands, is nearly 6 inches in length when alive.

The family *Polyceridæ* is distinguished from the *Dorididæ* by having non-retractile gills; the principal genera being *Goniodoris*, *Acanthodoris*, *Idalia*, *Ancula*, *Polycera*, *Plocamophorus*, *Triopa*, and *Ægirus*. *Ancula cristata* is an elegant little creature, about half an inch in length, occurring upon most of the British coasts. It is white, with the processes tipped with yellow or orange. The tentacles are laminated and non-retractile, each having two styliform appendages at the base. The gills are placed in the middle of the back, on each side of which there are a few compressed appendages.

Inferobranchiata. This division of Nudibranchs was established for a group of naked marine molluscs having the gills placed symmetrically along each side of the body between the margin of the dorsal mantle and the edge of the creeping disc. *Phyllidia* and *Pleurophyllidia* are the typical genera originally described, and may be regarded as the principal representatives of this group of molluscs. One group of Inferobranchs, however, is abnormal in being destitute of external branchiæ. In the genus *Phyllidia*, containing several very handsome species, the animal is somewhat depressed, and covered with a leathery and sometimes tuberculated mantle; the head is small and concealed between the foot and back; and the two oral tentacles are short, the dorsal pair retractile into cavities towards

the anterior end of the body as in *Doris.* The laminated gills extend the entire length on both sides. The vent is dorsal and at the posterior part of the mantle, and the reproductive organs are on the right side. In the disposition of the branchiæ these animals are very like the chitons and limpets. They are remarkable for possessing neither jaws nor radula, the mouth being modified into a sucker, as in the *Doridopsidæ.* These animals are so apathetic that they have never been observed to make any movement, but appear as if dead. They are inhabitants of tropical seas, the few species that are known occurring in the Red Sea and the Indian and Pacific Oceans. In the allied *Pleurophyllidia* the animals have at the anterior end a sort of shield above the head. The gills are situated as in *Phyllidia,* but the vent is on the right side. The mouth is provided with two strong jaws, and a well-developed radula. The dorsal tentacles are small, and situated between the mantle (*notæum*) and the head-shield, and not passing through

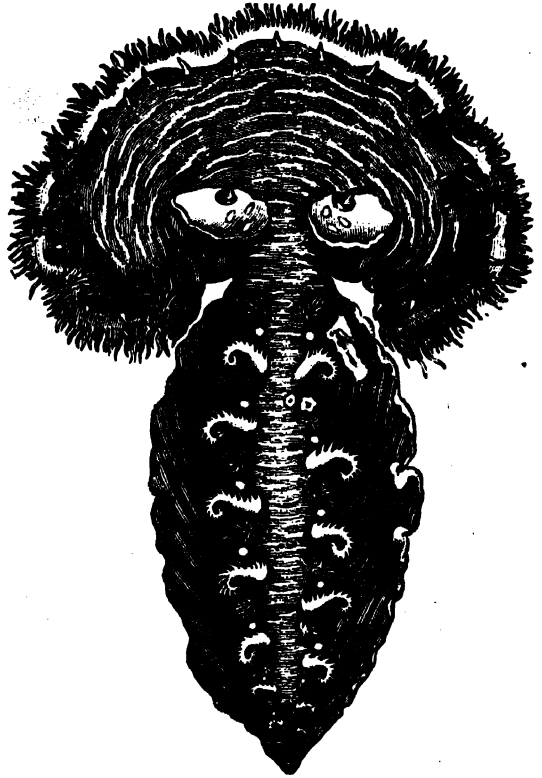


Ancula cristata (much enlarged).

the mantle, as in *Doris* or *Phyllidia. P. lineata,* from the Mediterranean, is a typical form of this genus. It is about 2 inches in length, of a golden colour, with longitudinal parallel whitish lines on the dorsal mantle.

Polybranchiata. This division of the Nudibranchs contains some of the most beautiful species of the entire order; and includes those forms which have the dorsal branchial processes arranged along the sides of the body, and not grouped around the vent, as in the Anthobranchiata. They have no spicula embedded in the skin. The branchial processes are sometimes simply cylindrical or linear, papillose or fusiform, but in other cases conspicuously branched. *Æolidia* is an example of the group in which they are unbranched, and *Dendronotus* exemplifies those in which the gills are branched. *Tethys, Melibe, Tritonia, Scyllæa, Glaucus,* and *Doto,* are, besides those already mentioned, some of the best known genera of the Polybranchs. *Tethys leporina* is a curious-looking animal, met with in the Mediterranean. The body is swollen, almost colourless, and transparent like the gills, contrasting wonderfully with the red-tipped dorsal processes

and the blackish irregularly white-edged dorsal eye-spots. It is vividly phosphorescent in the dark, and the phosphorescence at once appears if the creature is in any way disturbed. It is said to be lively in its movements, and capable of swimming freely in any direction; but has neither jaws nor radula. Specimens are sometimes captured 8 inches to a foot in length. In the genus *Tritonia* the branchiæ are numerous, and arranged in a row along the lateral margins of the back. There is a large frontal veil above the mouth as in *Tethys*, and the retractile tentacles are branched at the ends. The horny jaws are large, and the radula well developed. *T. hombergi* is the largest of the British nudibranchs, being sometimes 7 or 8 inches in length. It varies in colour from dark purple-brown to light brown, flesh-colour, and yellowish white. *Dendronotus arborescens* is one of the most beautiful of the naked Mollusca, the accompanying figure giving a good idea of the branched character of the gills. It will be noticed that they are arranged along each side of the tapering body, that the head-veil is also branched, and that the laminated tentacles are retractile within branched sheaths. The back is reddish or yellowish brown, marbled with darker brown, and spotted with white. The animal is about 2 inches in length, and has both jaws and radula. It is not uncommon on most parts of the British coasts, from low-water mark to deep water, and it also ranges northward to Greenland. It is also re-

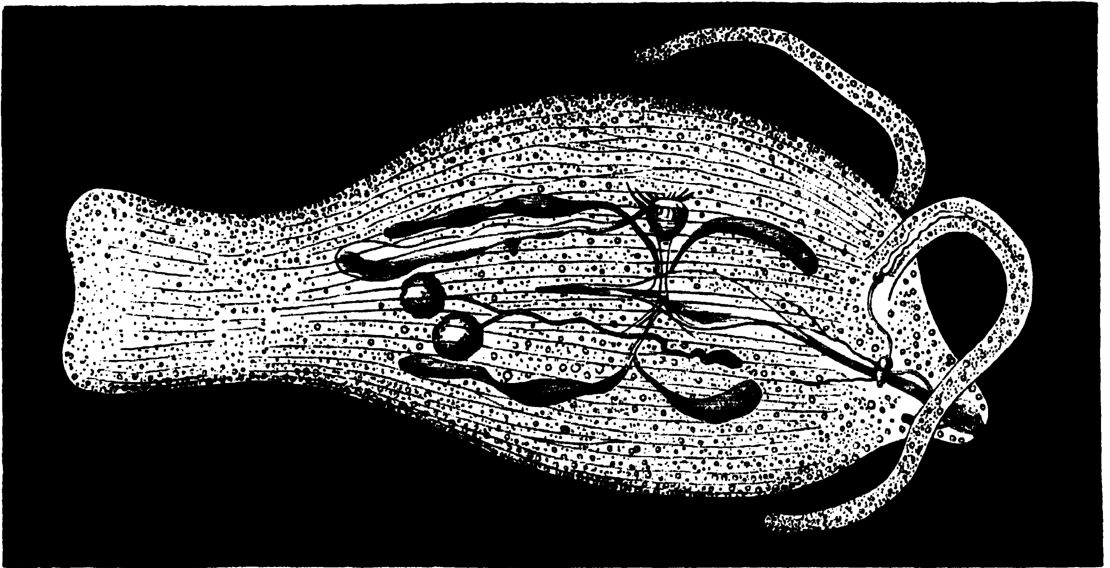


Tethys leporina.



Dendronotus arborescens (enlarged).

corded from the Atlantic coasts of North America, north coast of France, and some parts of the Baltic. The animals belonging to the genus *Scyllæa* live upon floating seaweed out on the high seas; *S. pelagica* being usually found upon the gulfweed of the Atlantic, which it resembles in its coloration. The foot is narrow, the sides being thin, and capable of clasping the stems of the seaweed. The body is much compressed laterally, and produced into two large leaf-like appendages on each side of the back, on the inner surface of which the tufted branchial processes are situated; a median supra-caudal crest also bearing branchial filaments. The tentacles are slender, laminated, and retractile within long compressed trumpet-shaped sheaths. The genus contains only a few species, but it has been found in almost every sea. *Phyllirhöe* is a genus of Nudibranchiata remarkable for the absence of both foot and gills. The body is compressed laterally, and so translucent that all the internal

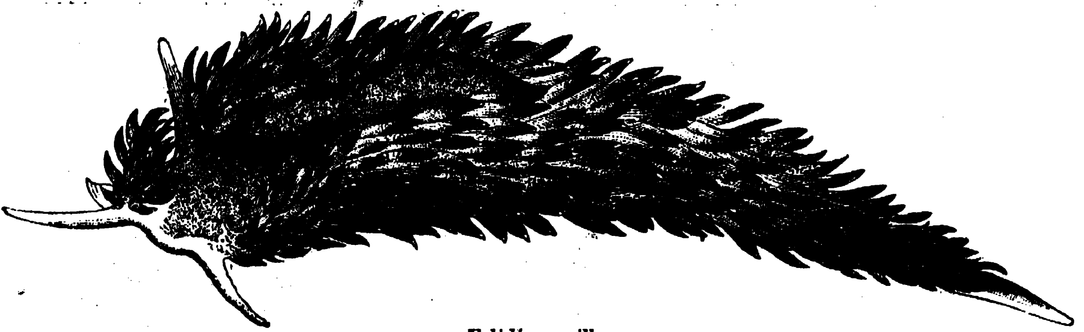


Phyllirhöe bucephala IN THE LIGHT, SHOWING INTERNAL ANATOMY (greatly magnified).

anatomy is visible. These animals are pelagic and eminently phosphorescent. Specimens kept in aquaria have been observed to be instantly luminous if touched.

In the *Æolidiidæ* the body is slug-like and tapering posteriorly. There are two labial and two dorsal tentacles, and the dorsal branchial papillæ are cylindrical or fusiform, and arranged in transverse rows on the sides of the back; the front of the creeping disc is often produced on each side in the form of tentacles; the horny jaws are large, and the radula consists generally of a single series of spinous plates. *Æolidia papillosa*, the largest of the British species, may be found under stones between tide-marks on many parts of the coasts. It is brown, grey, or orange, spotted with brown or purple and white; the dorsal tentacles are brown with white tips, and the papillæ are speckled with brown or lilac and white, with white tips. These molluscs are animal-feeders, partial to sea-anemones. Their fecundity is very great, as many as sixty thousand eggs being deposited by a single individual at one time. These are enclosed in a perfectly transparent

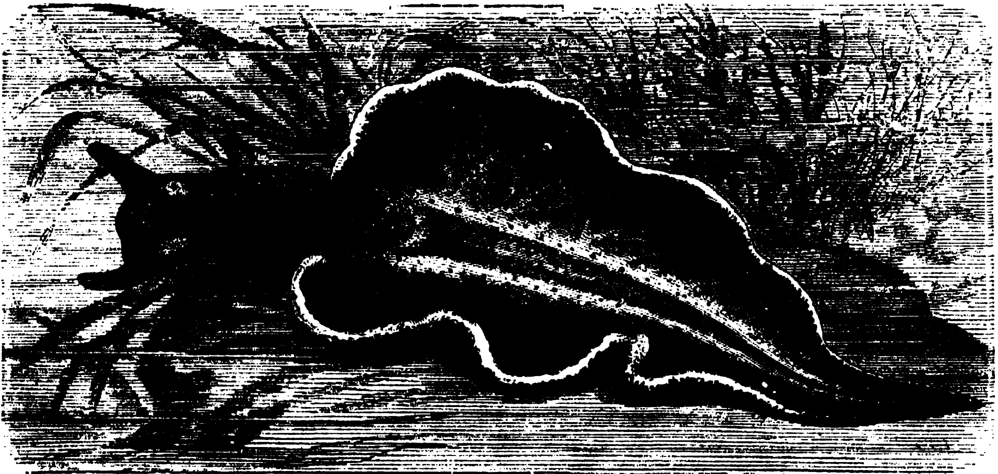
mucus, and the fry generally emerges in about ten days or a fortnight. Like *Scyllæa*, the animals known as *Glaucus* live in the open sea upon floating seaweed, and feed upon jelly-fish of various kinds. The form of the body is peculiar, having three lobes or expansions on each side, supporting the linear branchiæ. Pelagic animals generally seem to be either colourless or specially coloured, with a view to protection from enemies both above and below the surface



Æolidia papillosa.

of the water. Probably the blue colour of *Ianthina* is protective, as resembling that of the ocean water. The blue tint of *Glaucus* may also serve this purpose.

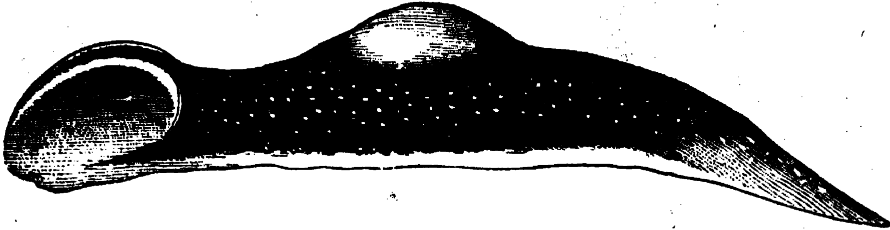
Pellibranchiata. This group of Nudibranchs comprises a number of forms which have no external branchiæ, but effect respiration through the general ciliated surface of the body. A typical example of this section is illustrated by the accompanying figure of *Elysia viridis* which is a little creature about an inch



Elysia viridis (magnified).

in length, of a dark green colour, varied with white, greenish blue, and reddish white dots. It lives upon seaweed, and, owing to its colour, is difficult of observation. The absence of external branchiæ is noticeable, and the ramified blood-vessels seen in the lateral expansions of the body are presumed to be connected with the respiratory function. This is the only species found upon the shores of Britain, and is most common on the south and south-west coasts. It is said to mimic the colour of the different seaweeds upon which it occurs. *Limapontia* is another

example of the Pellibranchs. It is slug-like in form, but without any tentacles. The species figured (*L. capitata*) is a minute animal, about a sixth of an inch in length, chiefly of a black colour, but occasionally somewhat transparent and colourless. Alder writes that "this curious little animal is probably pretty generally diffused, but on account of its minute size it may readily be overlooked. It is gregarious; and, wherever met with, it has usually been found in abundance, appearing when contracted like little black dots scattered over the conferva on which it feeds."



Limapontia capitata (much magnified).

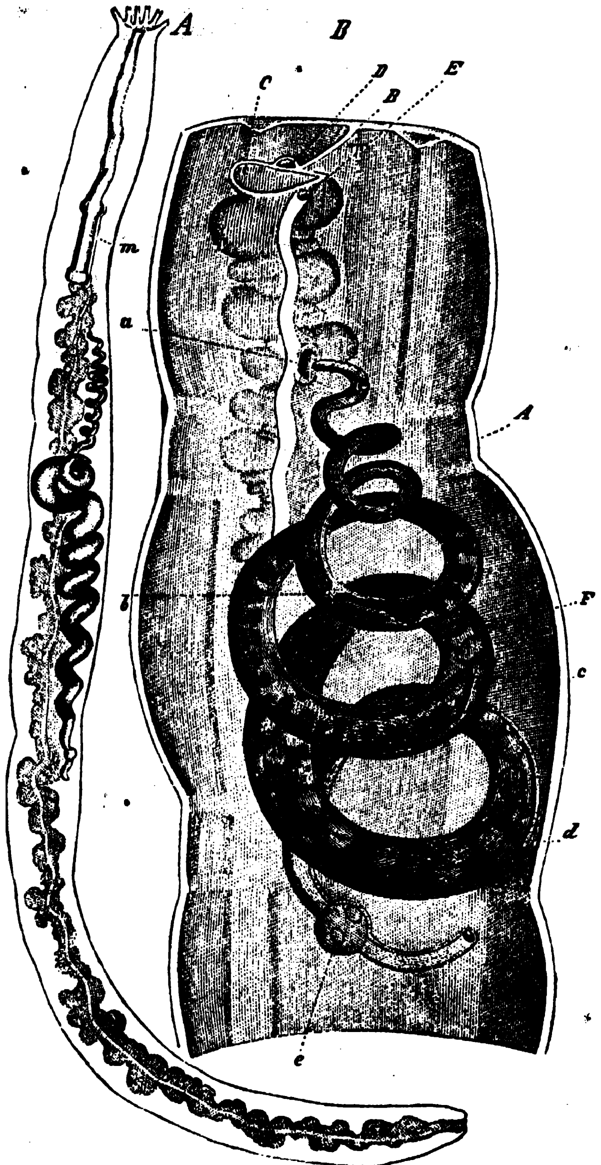
It lives between tide-marks, feeding upon small algæ, and deposits its ova in small pear-shaped capsules, each containing about one hundred eggs.

Parasita. The only form belonging to this group, the position of which is not settled, is the parasitic genus *Entoconcha*. The animal is worm-like and spirally coiled, and attaches itself by the oral end (*a*) to one of the blood-vessels (*E*), within the visceral cavity of a certain group of Echinoderms. One species is found in *Synapta*, and a second (*E. muelleri*) occurs in the trepang (*Holothuria*) of the China Sea. In the very early or larval state *Entoconcha* is contained in a minute operculated glassy shell. The subsequent changes between this and the perfect condition have not yet been observed. It is the lowest type of Nudibranchiata, if indeed it really belongs to that suborder, which is not absolutely certain, some authors even locating it near *Natica*. Were it not for the form of the larva, one would hardly have supposed that this worm-like creature belonged to the Mollusca at all. It has neither jaw nor radula, but the mouth is adapted for sucking. The sexes, as in the typical Nudibranchs, are united in the same individual. The female element (*b*) is somewhat anterior, the male organ (*c*) being at the opposite extremity. The central portion of the animal serves for a certain time as a nursing-pouch for the embryos, which subsequently are extruded at an opening at the posterior end. Only one out of every hundred or two hundred specimens of *Synapta* is infested with the *Entoconcha*. Pelseneer locates it next to *Eulima* among the Pectinibranchs.

Covered-Gill Subgroup,—Suborder Tectibranchiata.

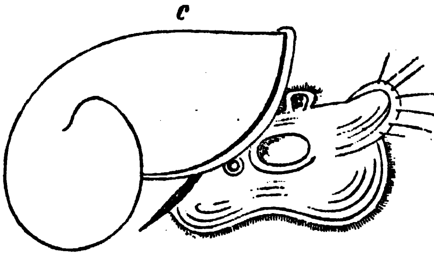
This constitutes the second suborder of Opisthobranchiata, and includes certain molluscs characterised by the possession of a lateral gill, protected by the mantle, or a shell. The members of the group are hermaphrodite animals, and differ from the Nudibranchs, not only in their respiratory organs, but also in the possession of a true mantle, which, in the Nudibranchs, is represented by the dorsal shield. On the other hand, they show affinity with certain

Nudibranchs in regard to the position of the rhinophores, the lateral expansions of the body, and the radula. Nearly all the Tectibranchs possess a shell which sometimes is wholly concealed beneath the mantle, sometimes partly covered, and, in many instances, wholly external. Some are carnivorous, others entirely phytophagous or vegetable-feeders; they mostly progress like an ordinary snail by means of the foot, but a few of them are free swimmers. The ova are generally deposited in long ribbons more or less coiled, and the embryos are provided with an operculated spiral shell. The Tectibranchs are classified in a number of families, separated from one another by differences in the general conformation of the animals, the shell, and the radula. The following are the more important genera:—*Actæon*, *Scaphander*, *Bulla*, *Acera*, *Aplustrum*, *Ringicula*, *Gastropteron*, *Philine*, *Doridium*, *Aplysia*, *Lobiger*, *Pleurobranchus*, *Umbrella*, and the aberrant *Siphonaria*. *Actæon*, of which about thirty species are known, is found in all seas. The animals are provided with a sort of head-shield, which is notched behind, and have the sessile eyes in front of the notch. They all are furnished with an ovate, often spirally punctate shell, which in some cases is prettily striped or spotted, and is capable of receiving the entire animal when contracted. In *Scaphander* the animal is too large to be wholly contained within the shell, and has an enormous head-disc; and the sides of the body are produced into lobes or epipodia, which can be partly reflexed over the shell. It has no visible eyes, as these would scarcely be of service to an animal which burrows into mud and sand in search of its food. Unlike many of the carnivorous Gastropods, which bore a hole in the victim's shell, and suck out the contents, *Scaphander* bolts



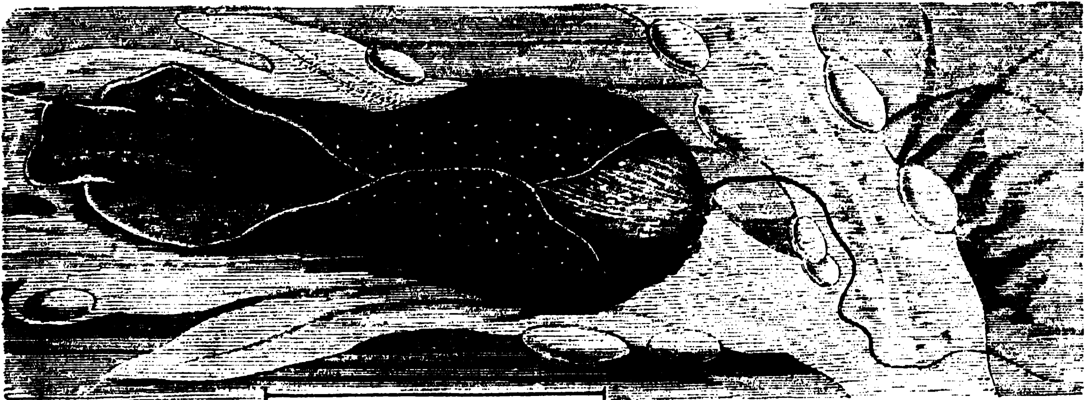
Synapta digitata, WITH PARASITIC *Entoconcha*, AND MIDDLE PORTION ENLARGED.

its prey whole, shell and all. The shell is then broken up by the aid of a very remarkable gizzard, and the soft parts digested. This gizzard consists of three strong calcareous plates of different size and form, which grind against one another by powerful muscles. The shells of *Scaphander* are mostly thin, spirally striated, oblong, convolute, without any visible spire, having the aperture narrow behind, and much wider in front. The known species are not numerous, and occur chiefly in seas of the Northern Hemisphere, but a few have been described from other parts of the world. *S. mundus* was obtained at the Aru Islands, at a depth of eight hundred fathoms, and *S. gracilis* off the Azores, in one thousand fathoms. By far the largest known form is the common British *S. lignarius*, which ranges from Finmark to the Mediterranean.



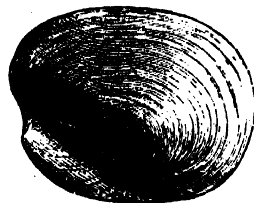
LARVA OF *Entoconcha* (much magnified).

The bubble-shells (*Bullidæ*), as this group is popularly called, are something like *Scaphander* in form, but rather rounder and stronger in their structure. Most of those belonging to the typical genus *Bulla* are prettily painted with blotches, clouds, and dots. The animal is not too large for its shell, has distinct eyes, and a different type of radula to that of *Scaphander*, which these molluscs resemble in their predatory habits. Another genus is represented in Britain by


Acera bullata (twice nat. size).

Acera bullata, which occurs on oozy ground and mud-flats in many estuaries. It also ranges from Finmark to the Mediterranean; and is remarkable for its thin, horny, convolute shell, with a slit at the suture, through which the animal protrudes a long, thread-like mantle-appendage. The side-lobes are largely developed, and can be reflexed so as to completely envelop the shell. They are also employed in swimming. Another family is represented by *Ringicula*, all the members of which are very small, not a quarter of an inch in length. The shells are entirely white, more or less globular, with a pointed spire, and with the aperture—which is notched in front—to some extent contracted with folds. The channelled character of the aperture is rather exceptional, the shells of the Tectibranchs being almost

exclusively holostomatous, that is, with uninterrupted apertures. *Gastropteron*, which typifies another family, is remarkable for the great lateral expansions, or epipodia, which are used by the animal in swimming. The gill lies exposed on the right side, the head-shield is truncate in front and pointed behind, and the mantle terminates behind in a slender, whip-like appendage. At one time this mollusc was supposed to be shell-less, but in reality an internal shell does exist; but, as it is only $\frac{1}{50}$ of an inch in diameter, it may be easily overlooked. *G. meckeli*, of the Mediterranean, is of a vivid red colour, with a few white spots, and a pale or bluish border to the lobes. In the *Philinidæ*, as typified by *Philine*, the shell is very thin, and wholly concealed beneath the mantle. In form it somewhat resembles *Bulla*, but has the aperture larger. *P. aperta*, a very common British species, lives in shallow water all round the coast, feeding upon foraminifera and even small sea-urchins. The animal is white, has a very large frontal-shield, but no tentacles or eyes. It is provided, as in the case of *Scaphander*, with a powerful gizzard. The ova, which are very numerous, are deposited in a single series, in a long and loosely-twisted cord, enclosed within an ovoid, gelatinous capsule.



Philine aperta (nat. size).

The sea-hares (*Aplysiidæ*), so called on account of a slight resemblance to a crouching hare, and not for their nimbleness of foot, are elongate creatures, with a long neck, distinct head, oral and dorsal tentacles, and furnished beneath the mantle with a shelly plate to protect the branchiæ. The mouth is provided with



SEA-HARE, *Aplysia* (nat. size).

horny jaws, and the gizzard is armed with horny spines, which prepare the food for digestion. The sides have large thin lobes, which are either folded over the back, or used in swimming. *Aplysia* includes both animal- and vegetable-feeders, inhabiting shallow water in all parts of the world. In olden time there were many stories in vogue respecting the poisonous nature of the sea-hare, but it has been shown to be harmless. It has the faculty of emitting a nauseous smell; and a beautiful purple fluid is discharged from glands in the edge and inner surface of the mantle. The species illustrated (*A. depilans*) occurs on the coasts of France

and in the Mediterranean. It is reddish brown, with irregular and variable greyish blotches and spots. It occurs in numbers on the Portuguese coast, and in stormy weather is sometimes cast upon the shores in such quantities as to be the cause of epidemics, and almost to render it worth while to extract the purple for economic purposes.

Of another family (*Oxynoidæ*), we may take as an example *Lobiger*, which includes elongate molluscs provided with a thin transparent shell, and having on each side of the body two long parapodia, used as fins in swimming. The animal has the power of casting off these lobes, and probably the posterior end of the foot can also be spontaneously detached. Four species have been described from the Mediterranean, Ceylon, Guadeloupe, and the Society Islands. They are separable on account of certain differences in the soft-parts, but in a conchological point of view they appear to be indistinguishable. In the family *Pleurobranchidæ*, the typical genus *Pleurobranchus* contains a number of species from many parts of the world, two of which occur on the British coast. The one illustrated (*P. peroni*) is a native of tropical seas, and was originally obtained from the Mauritius. The body is convex, ovate, with the mantle extending over the back, and having a free margin at the sides. Beneath this, on the right side, is situated the large branchial plume. The head is furnished with both labial and upper tentacles, and at the inner base of the latter are situated the eyes. A thin, membranous, flat shell is concealed beneath the mantle, over the back. *P.* (*oscanias*) *membranaceus* and *P. plumula* have both been found on various parts of the British coast. Both range as far as the Mediterranean. The spawn of *P. plumula* is deposited in ribbon-like and spirally arranged masses, resembling those of *Doris*.



Pleurobranchus peroni (nat. size).

The animal of the genus *Umbrella*, which typifies another family, is very large, and carries upon its back a flat, circular, external shell, recalling the form of an umbrella of the Chinese pattern. The gill, as in *Pleurobranchus*, is on the right side, beneath the mantle, and protected by the shell. This unsightly creature is remarkable for the enormous development of the foot, which extends everywhere beyond the margin of the shell, and practically encloses the head in front. One species occurs in the Mediterranean, and three or four others are met with in the Indian and Pacific Oceans. The shell of *U. indica* is sometimes fully 5 inches in diameter.

The families *Siphonariidæ*, *Gadiniidæ*, and *Amphibolidæ*, already mentioned, constituted, until recently, a suborder of Pulmonata, to which Gray gave the name Thalassophila. According to Haller, however, *Siphonaria* and *Gadinia* should be regarded as modified Opisthobranchiates, and placed next to the *Umbrellidæ*; but their systematic position cannot be considered definitely settled. The *Siphonariidæ* look like ordinary limpets, and attach themselves to rocks in the same way at

about high-water mark. The shells are distinguishable by a groove on the right side of the inner surface, interrupting the muscle by which the animal is attached. *Siphonaria* much resembles *Auricula* as regards the pulmonary cavity, which is adapted for breathing air or water, there being both a lung and a modified gill. It is, however, protected or closed by a valve-like lobe of the mantle. The horny jaw has a smooth and curved cutting edge. The radula consists of a single central or rachidian tooth and numerous laterals, very similar in type to that of certain groups of Pulmonata. About fifty species are known. The genus has an extensive range from Vancouver Island in the north to Cape Horn in the south. One species occurs on the coast of Portugal, but the majority inhabit eastern seas. In *Gadinia* the breathing-chamber is without any sign of branchiæ. It is a limpet-like animal with a circular foot by which it attaches itself to rocks or stones, in the same manner as limpets. It is probably a poor traveller. The pulmonary orifice is placed on the right side near the head, and is closed by a small valve. The head is large, without tentacles, with the sessile eyes placed at the sides. Mr. Dall, who watched a colony of *G. reticulata*, noticed that "as long as the rock on which they were remained damp, they continued with the margin of the shell firmly applied to it. As soon as the boulder became dry, under the hot sun, I perceived a simultaneous motion in the colony. Each shell was raised above the surface of the stone, the head and foot were protruded, and the orifice of the pulmonary cavity was expanded. They were evidently enjoying the warm air."

Suborder Pteropoda.

Until within the last few years, the molluscs included in this suborder were considered to constitute a separate class. Some systematists located the group near the Cephalopoda, others, believing them to be of a more degraded type than the Gastropoda, assigned them a position between that class and the bivalved Mollusca. Dr. Mörch and others, long ago pointed out the affinity of the Pteropods with the Opisthobranchs, and Dr. Pelseneer has come to the conclusion that these molluscs should be included in two of the Tectibranchiate groups of the Opisthobranchs. The Pteropods seldom come near land, except when driven by currents and tempests, and although they rise to the surface principally at night, they have been observed during the daytime. They are characterised by two delicate fins or lateral expansions of the foot (*parapodia*), placed at the anterior end of the animal, and used in swimming, being moved with considerable rapidity, like the wings of a butterfly. When they wish to sink, their fins are contracted, and the anterior part of the body, in some cases, is more or less withdrawn into the shell or the mantle, and they thus fall to the depth desired. At times they remain stationary, by keeping the fins merely extended. Some—*Clio*, *Pneumoderma*, for example—adhere to floating bodies by means of oral appendages provided with suckers, others by means of a sufficiently developed foot. The fins, termed *epipodia* by Huxley, are sometimes united, forming a single disc, sometimes partly connected, or, finally, entirely separated. The Pteropods are hermaphrodite, or have the sexes united in each individual. They deposit their ova in the form of long bands which float on the surface of the sea. They are

carnivorous in their habits, and live upon minute animals which abound in the sea, including small Mollusca, and Entomostraca and other Crustacea. Some of them possess prehensile organs for seizing their prey, but many appear to be totally unprovided with any special appendages for this purpose. In the early stages of development a shell always exists, but when adult, only certain forms are furnished with such protective covering, the others being naked molluscs. They possess a heart, consisting of auricle and ventricle, enclosed within a pericardium. The branchiæ are either internal or external. The head, distinct in some groups, and furnished with one or two pairs of tentacles, is practically wanting in others, and reduced to a mere mouth at the base of the fins. Nearly all the various forms have a radula, and some horny jaws. There are no eyes, or these are only represented by minute pigment dots upon the visceral sac, or on the tentacles. The fry of the Pteropods closely resembles that of ordinary Gastropods; but subsequently the frontal veil of the Pteropod disappears, and is replaced by the parapodia or permanent fins.

The number of species of this group is inconsiderable, and may be estimated at about fifty-four; but, as regards individuals, the numbers are inconceivable. The bottom of the sea in various parts of the Gulf of Mexico, the Bay of Biscay, and the Mediterranean, is paved with an accumulation of the dead shells of *Cavolinia, Cleodora,* and other forms. Their tiny forms occur in shoals in the tropics, and in more temperate seas, and, even in Arctic latitudes, they exist in such myriads as to discolour the water for considerable distances. They there form a large item in the diet of the Greenland whale. Some of the species have a wide distribution, occurring in the Atlantic, Pacific, and Indian Oceans, others are more localised.

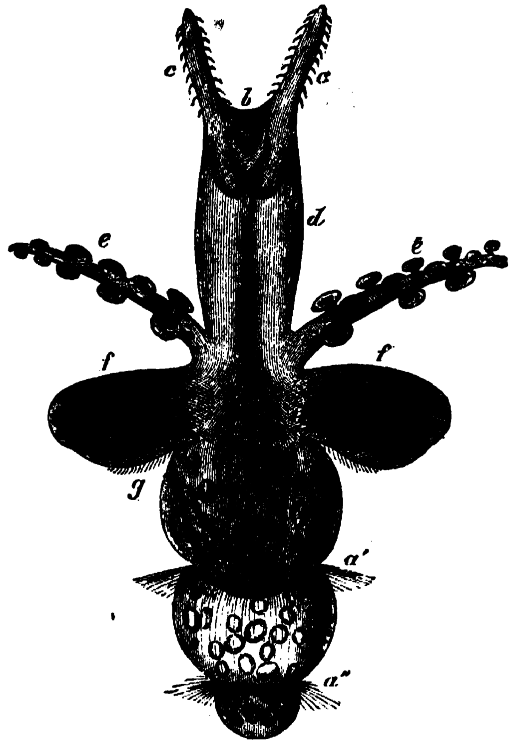
Gymnosomata.

The Pteropoda are divided into two sections, namely, Gymnosomata and Thecosomata. The animals belonging to the former group have no mantle or shell in the adult state. The body is generally elongate, the head distinct, and furnished with two pairs of tentacles, the posterior bearing rudimentary eyes. The swimming-lobes are attached to the sides of the neck, which is somewhat narrowed and constricted. The breathing-organ is external, lateral, or at the posterior end of the body. The foot is rudimentary and ventral. The radula is composed of numerous rows of teeth as in some of the Nudibranchs. The young at first are contained in a minute straight shell, and swim by means of a ciliated frontal veil (*velum*). Subsequently these structures disappear, and the larva progresses by means of circles of cilia which surround the body at intervals. In the final metamorphosis, the cilia disappear, the parapodia are developed, and the animal assumes the adult condition. The gymnosomatous Pteropoda are only few in number of species, but, like the rest of the group, occur sometimes in enormous numbers, and are very widely distributed. All are small creatures, the largest not exceeding an inch and a half in length; they are carnivorous, and often, it is said, feed upon their shell-bearing relatives. The position assumed by the Gymnosomata when swimming is vertical, with the head uppermost, or else slightly sloping.

The Gymnosomata are arranged in five families, comprising only seven genera, namely, *Dexiobranchæa, Spongiobranchæa, Pneumoderma, Clionopsis, Notobranchæa, Clione,* and *Halopsyche.* Dr. Pelseneer locates them next to the *Aplysiidæ.*

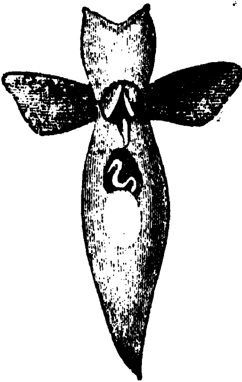
Thecosomata.

The forms belonging to this section of Pteropoda are characterised by the presence of a delicate external shell, by the foot being represented only by the two anterior symmetrical fins, by the existence of a mantle, by the absence of eyes, and (except in a few cases) of a gill. The head is indistinct and furnished with a single pair of tentacles. The mouth is unprovided with hook-sacs, as in the Gymnosomata. The radula has only a single lateral tooth on each side, with a small basal piece. The Thecosomata are divided into the three families, *Limacinidæ*, *Cymbuliidæ*, and *Cavoliniidæ*.



LARVA OF *Pneumoderma* (magnified).

The members of the family *Limacinidæ* possess a small sinistrally coiled shell, provided with a delicate glassy operculum, which is attached to the posterior lobe of the foot. The animal can withdraw completely within the shell, which, when the animal is swimming, has a lateral position, or possibly rests with the spire inclining somewhat downwards. Two genera are included in this family, namely, *Limacina* and *Peraclis*. In *Limacina*, of which ten species are known, the shell is rather globose, umbilicated, with a short spire, and the aperture somewhat prolonged at the base. The lip of the aperture is simple, but the columella is reflexed. The fins of *L. helicina* are broad and squarish at the ends and notched on the inner edge. The operculum is oblong, transparent, paucispiral, the nucleus being lateral. This mollusc lives in immense shoals in the Greenland seas, and it is one of those fed upon by various whalebone whales. Two species only are known of *Peraclis*. The shells are excessively fragile, sinistral, rather like a fresh-water *Physa* in shape, but having the aperture produced below into an acute rostrum. The animal has a minute glassy operculum, and differs from *Limacina* in having a distinct head, prolonged into a proboscis, and other anatomical characters. Both forms occur in the Atlantic, but *P. reticulata* is also known from the Pacific and the Mediterranean.



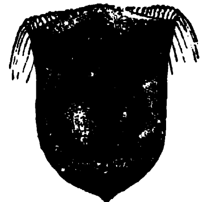
Clione (somewhat enlarged).

The molluscs of the family *Cavoliniidæ* have external, semi-transparent shells, which are non-operculate, bilaterally symmetrical, and not spirally coiled. They are variable in form in the different genera. The animals are completely retractile within the shell, and the form of the fins and of the hinder lobe of the foot varies consider-

ably. The mouth, lips, and tentacles are the same as in *Limacina*. Three genera are comprised in this family, namely, *Clio*, *Cuvierina*, and *Cavolinia*. *Clio* is subdivided by Dr. Pelseneer into four groups, *Creseis*, *Hyalocylix*, *Styliola*, and *Clio*. In *Creseis* the shell is elongated conical, circular in section, smooth, and the embryonic portion marked off by a deep constriction. The shell of *Hyalocylix* is elongate, conical, oval in section, with a recurved apex, and marked with transverse grooves and ridges. *H. striata*, the only known species of this genus, is cosmopolitan. *Styliola* has a slender tapering shell, sometimes an inch in length, and not more than a sixteenth of an inch in diameter at the aperture. It appears quite smooth and glossy, and, like *Hyalocylix*, occurs in all tropical seas. *Clio* is one of the most beautiful of all Pteropods. The shell is often rather triangular in shape, keeled along the sides, the lateral angles being sometimes produced into long, straight, sharp spines. It is of a most delicate glassy substance, and highly glossy. The so-called genus *Balantium* is synonymous with this group. Eight species are recognisable. The genus commonly known as *Cuvieria* contains only a single species (*C. columnella*), which has been obtained in the Atlantic, Indian, and Pacific Oceans. It is glassy, excessively thin, somewhat cylindrical, but produced posteriorly to an acute point. This narrowed portion is generally wanting in adult shells. In the soft-parts it closely resembles *Clio*, and it is chiefly on conchological grounds that it is separated. The genus *Cavolinia* is perhaps the commonest of all. The shell is generally pale horny brown, often globose, composed of a ventral and dorsal plate, which are united inferiorly, but not along the sides or above. The dorsal piece is flattish, and the ventral generally very globose. The shell is produced into a spine behind, and the sides generally terminate posteriorly in sharp points or spines. The animal somewhat resembles *Clio* in its external characters, but is remarkable for the presence of lateral prolongations of the mantle, which project through the lateral slits in the shell. Eight species are recognised by Dr. Pelseneer. *C. tridentata*, *C. uncinata*, *C. globosa*, and *C. trispinosa* are the best known.



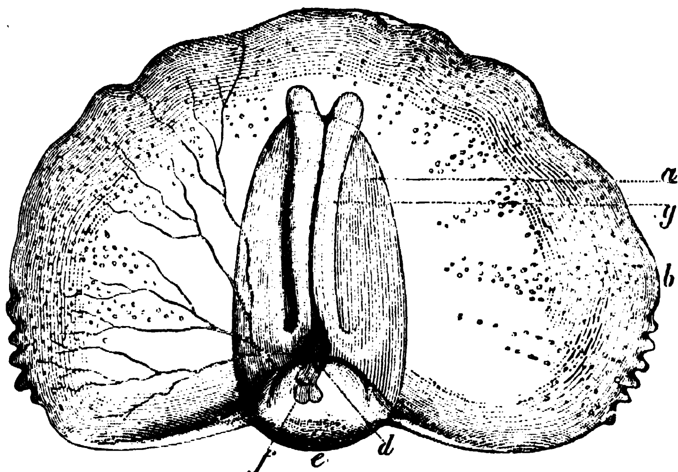
Cavolinia tridentata.



LARVA OF *Cavolinia gibbosa.*

In the family *Cymbuliidæ* the shell is very different from that of other Thecosomata. It is cartilaginous or gelatinous, bilaterally symmetrical, and somewhat resembles a slipper in general form. It is very easily detachable from the animal, and consequently a number of species, which in reality belong to this family, have been characterised as shell-less. Pointed at the ventral extremity and truncated at the dorsal end, it is covered with acute spine-like tubercles arranged in longitudinal series. The modified foot, or fins, are large and rounded. The animal is furnished with a radula. Of *Cymbulia*, two species are known. *C. peroni* is common in the

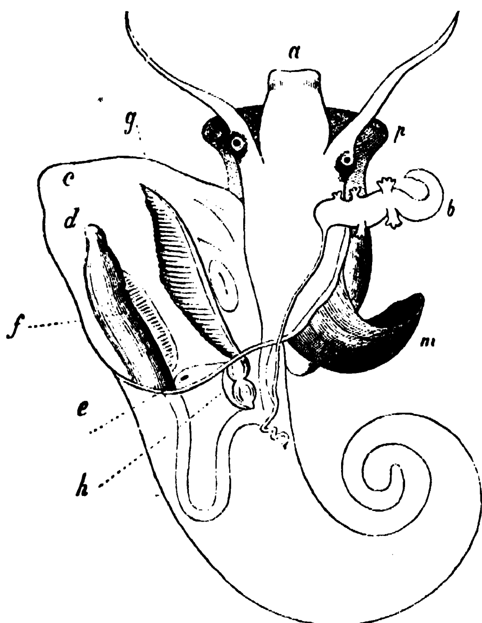
Mediterranean, and it probably also occurs in the Atlantic. The second species, of which only the shell is known, was found in New Zealand. *Cymbuliopsis* and *Gleba* are the two remaining genera of this family.



Gleba cordata. *a*, Body ; *b*, Fin ; *e*, Proboscis.

FRONT-GILLED GROUP,—Order PROSOBRANCHIATA.

The Prosobranchs, which include the majority of marine gastropods and a few groups of terrestrial forms, are always contained within or protected by a shell, and organised for crawling. The branchial or pulmonary cavity is in advance of the heart, and the auricle of the latter in front of the ventricle. This important anatomical character, which is expressed or referred to in the term Prosobranchiata, can best be understood by observing the accompanying figure representing the male of one of the periwinkles (*Littorina*). Here the respiratory organs are lodged in a chamber formed by the mantle behind the head; the gills are variable in the different suborders. In some forms, with nonspiral shells, they are double and symmetrical, but in others, and these are the majority, where the shell assumes a spiral form, the gill is usually single. Some of the Prosobranchs have horny jaws, but others are without; most are furnished with a radula, but this is sometimes absent. Characters derived from this organ have been largely employed in the classifications of the suborders. The sexes are separate; the head is distinct, and furnished with a pair of tentacles, sometimes having the eyes at the ends, but mostly at or near their base. An operculum, which is unknown among the Opisthobranchs and Pulmonates, except in the case of *Amphibola*, is developed in the majority of Prosobranchs, but the number of genera in which this appendage is absent is considerable. It assumes very different forms, and its size is very variable in proportion to the dimension of the aperture of the shell. In some



ANIMAL OF MALE PERIWINKLE, WITH THE SHELL REMOVED.

a, Mouth ; *b*, Sexual organ ; *c*, Reflexed mantle ; *d*, Vent ; *e*, Kidney ; *f*, Slime-gland ; *g*, Gill ; *h*, Heart ; *m*, Shell-muscle ; *p*, Foot.

genera it is as large as the aperture of the shell (*Ampullaria, Natica, Bithynia*), while in others it only partly closes it; and in other cases it is so small as to be of no use for closing the shell. It is mostly horny, but in a few instances is more or less thickened and strengthened with a shelly or calcareous layer. The horny opercula are mostly flattened, but in a few cases are thickened, or conical (*Torinia, Cœlopoma*). The shells of Prosobranchs comprise some of the most beautiful, and most prized by collectors. The order may be separated into three main divisions, namely, Pectinibranchiata, Heteropoda or Nucleobranchiata, and Scutibranchiata, severally characterised by differences, as the names imply, in the breathing-organ, coupled with other characters in connection with the genital organs, radula, etc.

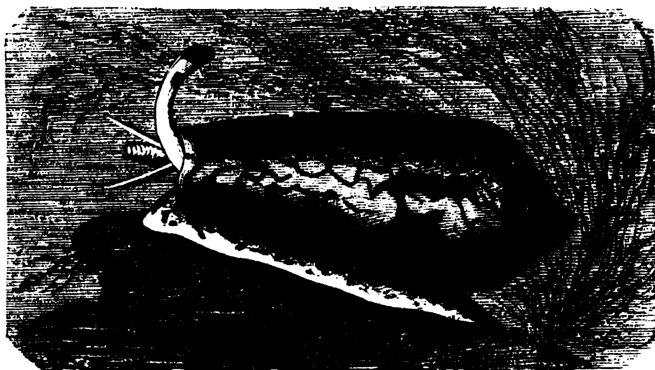
Suborder **Pectinibranchiata.**

The molluscs included in this suborder have the body twisted, and contained in a spirally-coiled shell. They are chiefly aquatic, and mostly marine, but a few families are strictly terrestrial. The gills are comb-like, that is, consist of plates arranged side by side and attached to a common stem, like the teeth of a comb to the thickened back. They are situated in a vaulted chamber, formed by the mantle over the neck, which is open in front for the admission of air or water. The Pectinibranchs have been subdivided into several sections, founded upon modifications of the radula or lingual ribbon. The following are the most important in the arrangement adopted by Paul Fischer, namely, Toxoglossa, Rhachiglossa, Tænioglossa, Ptenoglossa, and Gymnoglossa. A large proportion of the Pectinibranchs are furnished with a long proboscis, extensile and retractile at the will of the animal. In almost every instance, molluscs of this proboscis-bearing group are provided with shells which may be recognised by a notch or canal at the front of the aperture, through which the so-called siphon is protruded. This consists of a more or less elongate fold of the mantle, and conveys the water to the branchiæ. In another large section of the Pectinibranchs—Rostrifera—there is no extensile proboscis, but the head terminates in a more or less prolonged snout which is not retractile, and is termed the rostrum. These two groups, however, are now abandoned on the ground that better characters are furnished by the radula.

SECTION TOXOGLOSSA.

In this group, including the families *Conidæ, Terebridæ, Pleurotomidæ*, and *Cancellariidæ*, the radula is composed of two rows of long, barbed, marginal teeth. The cones (*Conidæ*) form an extensive family, containing about five hundred and fifty species. They have always been great favourites with collectors, on account of the great beauty and variety of the colour-markings, and are almost exclusively tropical, only a few species ranging northward to the Mediterranean and Japan. Some of them have a very wide distribution, being found in the Red Sea, Indian Ocean, and in various parts of the Pacific. Others, on the contrary, have an equally limited range. These animals are all predaceous, having a short strong foot, truncate or square in front, and pierced with a water-bearing pore at the anterior part. The head has two slender tentacles, with the eyes on the outside

near the middle. The siphon is long, and protruded through the notch at the anterior or narrow end of the shell. They are not very active creatures, but crawl about slowly in holes in the rocks, or fissures of coral-reefs, in depths ranging from low-water mark to thirty or forty fathoms. The shells are generally strong and solid, and as the animal grows and requires more room, it absorbs the early whorls, leaving only a very thin partition between them; but, in order to preserve the proper weight of the shell, it thickens up the spire within. All the species are formed on one plan, but the extremes vary considerably in form. This variation, difference of sculpture, periostracum, and colour, constitute the characters upon which the species are founded. Some of the handsome and rarer forms fetch very high prices. *Conus cedo-nulli*, which is found in the West Indies, is, besides being rare, remarkable for the variation of its colour-markings. *C. cervus*, *C. adamsoni*, *C. thomæ*, *C. nobilis*, and *C. delessertii*, are some of the most highly treasured, but the celebrated *C. gloria-maris*, from the Molucca and Philippine Islands, of which only about a dozen specimens are known, is still considered the finest shell of all, and a full-grown specimen in good condition would probably now realise about forty or fifty pounds. Some, such as *C. betulinus* and *C. suratensis*, are extremely solid, but a few, *C. geographus* and *C. tulipa*, are very thin. It has been asserted that certain species have no operculum, but this is now believed to be incorrect. This structure is small, horny, narrow, and, being much smaller than the aperture of the shell, in no way serves the purpose of defence. A large number of fossil species have been described from the Tertiary formations. Some instances are on record of persons having been bitten by cones when handling them, and it is said that the bite, to some extent, is poisonous, but whether this character is peculiar to a few, or common to all the species, we have no means of knowing.



TEXTILE CONE, *Conus textile* (nat. size).

The auger-shells, *Terebridæ*, have a very different appearance to the cones, and conchologically do not exhibit any particularly close relationship; although the characters of the dentition certainly indicate their approximation. The molluscs of this family have a small head with two small cylindrical tentacles, with minute eyes at the tips. The foot is small, rounded in front, and elongate behind, and supports a small, oval, horny operculum, with an apical nucleus. About two hundred and thirty species have been described. They abound in tropical regions, but a few occur in more temperate localities, such as Japan, California, and New Zealand. Some of the shells are so solid (*Terebra maculata*), and others so extremely elongated (*T. pretiosa*, etc.), that it would appear impossible for the animals to carry them erect. Probably, in these instances, the shells are dragged along resting upon the surface of the sand. They are all elongate in form, with

a small aperture, notched in front for the passage of the siphon. The whorls are flat and generally divided below the suture by a spiral furrow. They are longitudinally fluted, smooth or noduled, and it is upon these differences in sculpture that the various subgenera are founded.

The third family—*Pleurotomidæ*—contains an enormous number of species, certainly more than a thousand having been described. They are mostly small, and show great variety in form. The species of the typical genus *Pleurotoma* are spindle-shaped, that is, have a long tapering spire at one end, and a prolonged beak or canal at the other, and the outer lip has a distinct slit somewhat below the suture. In *Surcula* and *Drillia* the slit or notch is at the suture, in *Bela* it is indistinct. Some forms, *Clavatula* and *Pusionella*, have a semi-ovate operculum, with the nucleus lateral; in *Pleurotoma*, *Drillia*, etc., it is ovate-pyriform, with a terminal nucleus; whilst in *Mangilia*, *Cythara*, etc., it is altogether absent. *Columbarium*, containing only a few species, is remarkable for the great length of the anterior canal, and the spine-like ornamentation of the whorls. *C. pagodoides*, dredged off Sydney in four hundred and ten fathoms, is one of the most beautiful of all the family. All degrees in the length of the canal are observable, until we find it reduced to a mere notch at the base of the aperture. *Pleurotomidæ* exist in every sea, but certain groups are more characteristic of cold and temperate climates. *Bela*, for instance, may be regarded as a representative northern genus; whereas, on the other hand, *Cythara* and *Pusionella* are tropical. They are generally rare in individuals, although numerous in species. They occur at all depths, from low-water mark to two thousand or more fathoms; indeed, a very delicate form, about an inch in length,—*Clathurella monoceros*,—was dredged in mid-Atlantic, to the south-west of Sierra Leone, in two thousand five hundred fathoms. The extinct forms of this family, occurring chiefly in the Tertiary deposits, are perhaps as numerous as those now living.

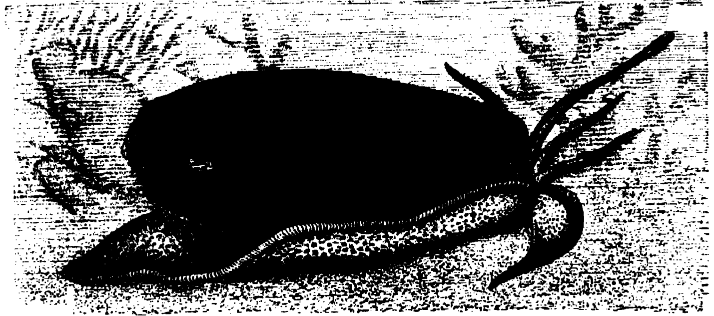
In the family *Cancellariidæ* the proboscis is small or rudimentary, the foot small, the siphon very short, while the eyes are placed at the outer base of the tentacles; the operculum being wanting. The Cancellarias have very beautiful shells, generally elegantly sculptured with longitudinal and spiral ridges, producing a cancellated surface. The forms are variable; some are oval, others turreted, and the most remarkable of all (*Cancellaria trigonostoma*) has the spire drawn out like a cork-screw. A constant feature in this family consists of three or four folds, plaits, or plicæ upon the columella. A few of the species are common, but many are extremely rare. About a hundred different forms are known. They are mostly tropical, but the genus *Admete* has a more northern range, extending as far as Greenland. They are usually obtained in shallow water, but a few specimens have been dredged at a depth of nearly seven hundred fathoms.

SECTION RHACHIGLOSSA.

This group of Pectinibranchs includes a large number of genera and species superficially very different. They are all marine gastropods, with a well-developed extensile proboscis, sometimes as long as, or even longer than the body. The radula is generally long, narrow, and armed with three teeth in a transverse row,

one central or rhachidian, and one lateral on each side; the latter, however, are wanting in certain groups. The respiratory siphon is rather long, fitting into the anterior canal or notch of the aperture. The eggs of these molluscs are deposited in strong leathery capsules, each capsule often containing a large number of ova. The genus *Yetus*, however, which is viviparous, produces a comparatively small number of young. All have shells, which in nearly all cases are capable of sheltering the entire animal. The principal families in this group are the *Olividæ*, *Harpidæ*, *Marginellidæ*, *Volutidæ*, *Mitridæ*, *Fasciolariidæ*, *Turbinellidæ*, *Buccinidæ*, *Nassidæ*, *Columbellidæ*, *Muricidæ*, and *Corolliophilidæ*.

The Olives (*Olividæ*) are mostly cylindrical shells, often beautifully ornamented with markings of various patterns, and always having a highly glossy or enamelled appearance. The aperture is narrow or notched in front, and the columella is not strongly plaited as in some of the families which follow (*Marginellidæ*), but there are numerous, slight, oblique folds, some of which pass round the base or anterior part of the shell, which is thus marked off from the rest of the surface into a distinct area. The animal has a very large foot, capable of covering the shell to a great extent, pointed behind, and with its anterior portion (*propodium*) divided into two lobes. The head is small, with pointed, slender tentacles, and the eyes about midway along their outer sides. The mantle is produced in front into a slender appendage, which protrudes with the breathing-siphon through the notch of the aperture; posteriorly it terminates in a thread-like process, which passes up the channelled suture of the spire. There is no operculum. The olives are very active, and burrow in the sand in search of bivalves; and are sometimes seen in countless numbers, the sands at low tide for miles being covered with them. Although about one hundred and fifty to two hundred species, mostly tropical, have been described, a few extend to more temperate seas as far north as Japan, and southward to Patagonia. The olives are frequently used in the manufacture of shell-ornaments. The genus *Olivella* differs from the typical *Oliva* in having neither tentacles nor eyes, and the spire of the shell is longer and more pointed. *Ancilla*, another important genus, comprises a number of polished species, which are nearly always of a uniform white, yellow, fawn, brown, or reddish colour, and without the markings of the olives.



BLACK OLIVE, *Oliva maura* (nat. size).

The family *Harpidæ* contains but a single genus, the well-known harp-shells (*Harpa*). These are strong, broad, ventricose structures, highly coloured, and adorned with numerous curved ribs, running parallel with the outer lip of the aperture. The columellar margin is smooth, and covered with a thin brilliant callus. The animal has an enormous foot, which is not wholly retractile within

the shell; and when disturbed it not unfrequently casts off the hinder part. About ten species are recognisable. They occur in the Red Sea, many parts of the Indian Ocean, Philippine Islands, South Sea Islands, Panama, and on the west coast of Africa and at Ascension Island. The members of the family *Marginellidæ* are mostly small, some very minute, but many of them have very beautifully coloured and highly polished shells. Nearly all are tropical, and many of the finest and most valued are inhabitants of the West and South African coasts. They are mostly ovoid, or subconoidal in form, with rather contracted apertures, slightly notched in front; the outer lip is involute and thickened, and the columella has a few oblique plaits upon the lower or anterior portion. There is no operculum; and, as in the majority of the volutes, the radula has only a central row of teeth. In *Pseudomarginella*, from Gorée, on the west coast of Africa, the shell is identical in every respect with *Marginella glabella* of the same locality, but the mollusc and its operculum are said to belong to the *Buccinidæ*.

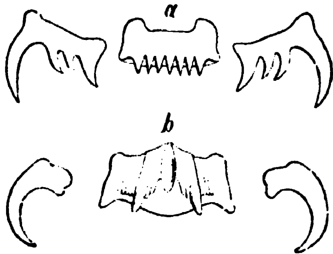
Nearly all the species of the family *Volutidæ* have large showy shells, and some of them, on account of their extreme beauty and rarity, realise very high prices. As in the *Marginellidæ*, the columella exhibits a number of oblique folds, but the aperture is rather more deeply notched in front for the passage of the siphon. The form of the shell is variable; in some the spire being very short, and scarcely rising above the last or body-whorl; while in others (*Zidona*) it is drawn out into a conical spire. The apex is sometimes (as in *Yetus*) enormous, and all intermediate sizes occur until we come to *Volutilithes*, in which it is quite small. This latter genus—a very common Eocene fossil of the London and Paris basins—has very feeble columellar plaits, and is now represented by a single species obtained in one hundred to one hundred and fifty fathoms off the Cape of Good Hope. The animals of the volutes are large, sometimes incapable of withdrawing entirely within the shell, and mostly without an operculum. The radula usually has only a single row of teeth, but, in a few instances, a lateral on each side is present. The *Yetus* shells are large, thin, with enormous apertures, having three or four strong, oblique plaits on the columella. They are found on the west coast of Africa, in the Indian and Pacific Oceans, and also off the Philippine Islands. *Y. proboscidalis* is viviparous, and produces four or five young at a time, about an inch long. The flesh of this enormous animal is said to be eaten, after being dried in the sun, by the natives of Senegal. As an example of the genus *Voluta*, we may mention the handsome West Indian *V. musica*, popularly known as the music-shell, from the colour-markings, which resemble the lines and notes of music. It is one of the few forms provided with a small horny operculum, and on this account has been placed in a distinct genus (*Volutolyria*) by some writers. Like the rest of the true volutes, it is oviparous. The allied genus *Volutomitra*, as the name implies, has affinities both with *Voluta* and *Mitra*; the shell and animal being for the most part mitroid, but the tongue resembling that of the volutes. It may therefore be regarded as a link between the two families. Three or four species are known, one from the shores of Greenland, and two or three from Tasmania and Kerguelen Island. The largest member of the *Volutidæ* (*Cymbium broderipi*), which is found at the Philippine Islands, sometimes attains a length of 14 inches and 30 in circumference. Rather more than a hundred species of this family are known.

The gorgeously-coloured mitre-shells (*Mitridæ*) always have been and still remain a favourite group with collectors. Like the Marginellas, they have no operculum, and are small in comparison with the volutes, but they equal if not surpass them in the beauty of their colour-markings and surface sculpture. The columellar lip is always plaited, the hinder plaits being the strongest. A remarkable feature of the genus, at all events in some instances, is the enormous length of the proboscis, which seems to be out of all proportion to the animal. The tongue of the mitras has three rows of teeth, all serrated in some species, but in others, with the two laterals simple, and of a somewhat different type. The common *Mitra episcopalis*, a striking, scarlet-spotted, heavy shell, is abundant at the Philippine Islands, and occurs in Ceylon and in Polynesia. The animal is sluggish in its movements, and buries itself in the sand when the tide recedes. The mitras with simple lateral teeth are mostly ornamented with longitudinal ribs or plicæ, and constitute the group *Turris*. Some frequent coral-reefs, and others are found, often in considerable numbers, crawling upon the sands in sheltered and shallow bays. Over five hundred species of *Mitridæ* are known. They abound in the islands of the Indian and Pacific Oceans, and seem to be scarcer on the shores of the great continents. They are not very numerous in the Atlantic, and even the tropical islands of the West Indies produce but an insignificant number, of unattractive form. *Mitra zonata*, found in deepish water off Italy and in a few other parts of the Mediterranean, is a fine species, and one of the rarest of the family. A few species of *Mitridæ* range as far north as Japan, and others occur at the Cape of Good Hope and New Zealand.

The tulip-shells, forming the family *Fasciolariidæ*, are mostly fusiform (spindle-shaped), some having very long spires and anterior canals. They never have a thickened lip to the aperture, which is often grooved and striated within. The typical genus *Fasciolaria* and also *Latirus* exhibit oblique folds on the columella, a feature absent in the slender *Fusus*. All are furnished with a horny operculum. The radula has three rows of serrated teeth, the central tooth being narrow, and the laterals broad. *Fasciolaria gigantea*, from the coast of South Carolina, is one of the largest gastropods, attaining a length of 2 feet. In *Leucozonia*, a group of the genus *Latirus*, the outer lip of the shell has a more or less prominent spine-like tooth in front. In *L. cingulata*, from Panama, it is sometimes five-eighths of an inch in length, and although it appears as if it would be a hindrance to the animal when crawling, it doubtless serves some purpose in its economy. The allied family of the chank-shells (*Turbinellidæ*) is not numerous in species, but contains several large and interesting forms. They are grouped together, on account of a similarity in dentition. The radula has three rows of teeth, the central tooth being nearly always three-pronged, and the laterals generally armed with a single or two unequal cusps. The typical species of *Turbinella* have very solid, heavy, pear-shaped shells, covered with a thick, fibrous periostracum, and exhibit a few strong oblique folds on the columella. The *T. scolymus*, a West Indian form, is sometimes 18 inches long. In India, *Turbinella* is largely used in the manufacture of carved bracelets, anklets, necklaces, and other ornaments. They are known under the name of chank-shells, and a fishery is carried on in the Gulf of Manaar. Occasionally sinistral examples are obtained, considered sacred by the Hindus, and also valued by the Buddhist priests of Ceylon and China. In *Cynodonta*, another group

of *Turbinellidæ*, the shells are compact and very strong, tuberculous or spiny, with short spires, and the anterior canal considerably shorter than in *Turbinella.* The aperture is armed with a few folds on the middle of the columella, and is closed by a thick and somewhat twisted operculum. The eight known species are distributed over the Red Sea, Philippine Islands, Polynesia, Pacific coast of Central America, and the West Indies. *Fulgur* and *Melongena* both include large striking shells from the United States and West Indies; and *Sycotypus canaliculatus*, also from the States, is remarkable for the deeply channelled suture separating the whorls. The egg-capsules are very curious, consisting of a long string of round discs, about the size of a shilling, but somewhat thicker, attached to the cord by one edge. Each capsule contains a number of eggs, and the young eat their way out at a spot opposite the points of attachment. *Semifusus colosseus* is one of the largest living gastropods, attaining a length of about 14 inches. It is an inhabitant of the Indian Ocean, and also occurs at the Philippine Islands. Another giant is the well-known *Fusus proboscidiferus*, of which the broadly fusiform shell sometimes attains a length of 2 feet. It is found on the west and north-west coast of Australia, and on account of the peculiar nucleus of the spire has been placed in a separate genus, *Megalatractus*. The egg-capsules form a cylindrical mass marked with a dozen longitudinal equidistant ridges, and divided off into compartments, each compartment containing from twenty to thirty young. When they quit the egg-case, they are about an inch in length, and bear no resemblance to the full-grown shell.

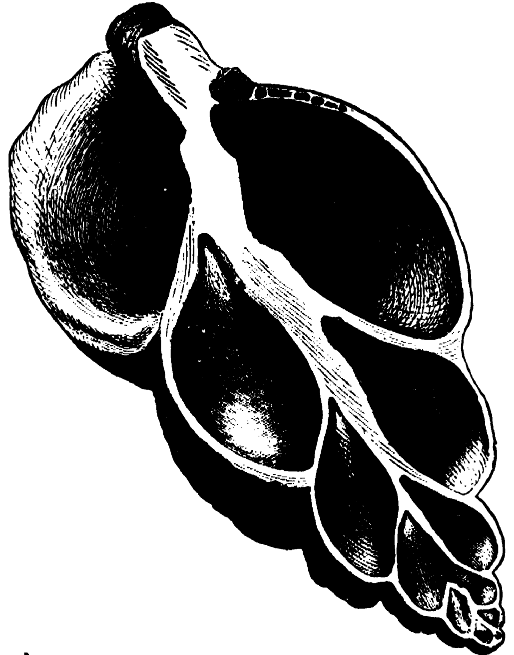
The whelks form the characteristic group of the family *Buccinidæ*, which also includes a considerable number of other genera, and numerous species. The animals usually have a long siphon and a large foot, more or less square in front and somewhat pointed behind; the head is provided with a pair of tentacles which support the eyes on the outside. The lingual ribbon is well-developed, with three rows of pronged teeth, the central with three to six cusps, the laterals two- or three-pronged. The form of the shells is variable; some are fusiform, with a distinct anterior canal, others ovate, with the canal reduced to a mere notch. All are provided with a horny operculum, which assumes different forms in the various genera.



ROW OF TEETH FROM THE RADULA OF (*a*) *Buccinum undatum*, (*b*) *Murex erinaceus*.

Chrysodomus is essentially a northern or Arctic race, and one of the fusiform types with a distinct siphonal canal. *C. antiquus*, the largest of the British marine gastropods, was also common in the English Crags. Reversed or sinistral specimens were the commonest form in the Red Crag. *C. contrarius*, found living on the coast of Spain and Portugal, is a closely allied species. *Sipho, Volutopsis*, and *Jumala* are other northern fusiform groups, which have a few British representatives. The common whelk (*B. undatum*) is the typical representative of the genus *Buccinum*, and is such a familiar object that a description of the shell is needless. We may, however, direct attention to the variations existing in this species, these being due to difference of locality, depth, etc. Specimens from deep water have much thinner shells than shallow-water forms, and those found on some

parts of the Northumberland coast are remarkable for their solidity. Thousands of bushels of this mollusc are annually consumed in London alone, and as much as £12,000 has been realised in a year by the whelk-fishery off Whitstable. Whelks are used as bait in the cod-fishery. The operculum of this species is roundly ovate, formed of concentric layers, the nucleus being a little excentric. It is comparatively small, and of no use as a defensive door to the shell. On the coast of Kent and Sussex a race exists, provided with two and sometimes three small opercula, instead of one as usual. It is a peculiarity which apparently has become permanent to some extent, but how it originated is a matter of conjecture. The whelk has a wide geographical range, occurring all over the North Sea to the Norwegian Coast, as far north as Iceland, and on the east coast of the United States from Cape Cod northwards. It is found fossil in the Coralline Crag. Owing to the variability in the shell, a considerable number of so-called species of *Buccinum* have been described; but the total of recognisable forms does not probably amount to more than about sixty or seventy. These are mostly Arctic or northern, but a few are known from Japan. *Volutharpa* is scarcely separable from *Buccinum*, but the shell is thinner, and the aperture very large. On the contrary, the operculum is minute, that of *V. perryi* from the Japanese seas—a shell about 2 inches long—being only about $\frac{1}{14}$ of an inch in diameter. *Neobuccinum* is the Antarctic representative of *Buccinum*; the single known species occurring at Kerguelen Island in the Southern Ocean. The operculum differs from that of *Buccinum* in being somewhat spiral, instead of concentric, and the lingual dentition is slightly different. *Cominella*, *Cyllene*, *Tritonidea*, *Pisania*, and *Euthria* are genera referred to the family *Buccinidæ*, on account of general similarity in the animals, and especially of the radula. They comprise a considerable number of species from tropical and temperate localities, but are not of sufficient interest to be further mentioned. We may, however, call attention to the genus *Euthria*, as a remarkable instance of wide geographical range. The typical species, *E. cornea*, which is very common in the Mediterranean, has also been found on the coast of the island of New Caledonia, eastward of Australia. The genus *Phos* contains a small number of very beautiful species with highly ornamental cancellated sculpture. On the other hand, the closely allied *Eburna* is remarkable for the smoothness of the shell, and the spotted character of the colour-markings.



SECTION OF WHELK (nat. size).

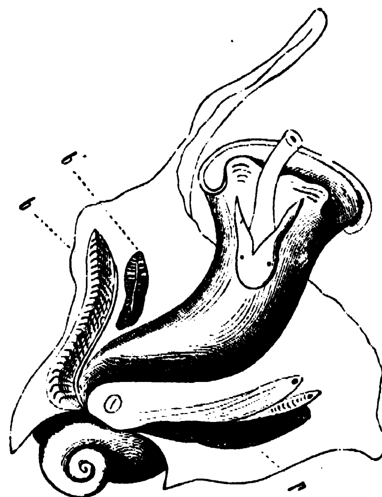
All the members of the family of dog-whelks (*Nassidæ*) are comparatively small, none exceeding 2 inches in length. The animal frequently has the foot—

which is large—bifurcated behind. The radula differs from that of the *Buccinidæ* in having the central tooth curved and finely serrated. The typical genus *Nassa* comprises an extensive group of small molluscs, which exhibit a considerable amount of variation in form and sculpture; and upon these characters many subdivisions have been proposed. The shells are mostly solid, ovate or turreted, smooth, granulated, or longitudinally ribbed. The aperture has a distinct oblique siphonal notch, the columella is more or less coated with callus, and the outer lip is thickened and denticulate, or grooved within. About two hundred and forty species are recognisable, of which three are met with in Britain. The majority are found in tropical seas. They often occur in immense numbers, and burrow in sand and mud in search of bivalves. The operculum is often somewhat triangular, with fine serrations along the sides. *N. reticulata*, the largest of the British species, is common all round the coast. It is a great nuisance on oyster-beds, and although exhibiting a preference for young oysters, also attacks those of more mature growth. The egg-capsules are roundish, very compressed, and attached by a short stalk to seaweeds. They are arranged close together in compact series, and have a small hole at the top, through which the young escape. The subgenus *Demoulia* resembles *Nassa* as regards the shell, but the animal (of *D. retusa* at all events) has no prolongations at the posterior end of the foot. The operculum is present in some species, wanting in others. Four of the seven known species are from West and South Africa, and one or two are said to be Japanese. *Cyclonassa*, another subgenus, agrees with the typical *Nassa* as regards the soft-parts, but is characterised by a very aberrant form of shell. This is smooth, flattened, somewhat like a *Nerita*, and has an oblique distorted look about the aperture. *C. neritea* is a very common Mediterranean shell; two other species being known, one also Mediterranean, the other from the Black Sea. In the genus *Bullia* the animal is very similar to that of *Nassa*, but the foot is larger, and the eyes are wanting. The shells are mostly smooth, and the suture between the whorls is generally filled up with a deposit of callus. The south of Africa may be regarded as the metropolis of this genus, but a few species also occur on the west and east coast, and in Mauritius, Madagascar, and Patagonia.

The dove-shells, or *Columbellidæ*, are likewise a very numerous family as regards species, upwards of three hundred having been described. The animal is similar to that of the *Buccinidæ*, but the central tooth of the radula is not armed with cusps, and the laterals are of a peculiar type. The shells are all small, some quite minute, and offer considerable variation in form and sculpture. Most of the species are prettily coloured, and many occur in enormous numbers, and are employed in the manufacture of shell-boxes and other ornaments. *Columbella* abounds in the tropics, but many are found in temperate latitudes all over the world, and two species belong to the British fauna. All are carnivorous and mostly littoral, but some affect depths of five or six hundred fathoms.

The extensive family of the *Muricidæ* contains some of the handsomest and most striking forms of all the Rhachiglossa. The animals have a moderate-sized foot, squarish in front and somewhat pointed behind; the tentacles are slender and pointed, supporting the eyes on the outer margin. The siphon is long, and the retractile proboscis, containing the radula, is well developed. The latter is long and

narrow, with three rows of teeth; the central tooth having three principal cusps or spines, and other secondary denticles, and the laterals being simple. The horny operculum is variable, having either a lateral or terminal nucleus. The shells exhibit much diversity of form in the different groups. Murices are carnivorous, feeding upon other molluscs, both gastropods and bivalves. In the typical genus *Murex* the animal, as it increases in size, produces at intervals beautiful foliations or spine-bearing ridges, nearly always three or more on a whorl, which are sometimes continuous up the spire; the siphonal canal being sometimes remarkably long and slender, almost closed and nearly straight. In this group many of the species are armed with numerous long spines upon the ridges; *M. tenuispina* from the Indian Ocean, Philippine Islands, and neighbouring localities, being a striking example. In the section *Chicoreus* the shells are strong, with three beautifully branched ridges, and the canal shorter than in the preceding group; *M. ramosus*, a large and abundant species from the Red Sea, Indian Ocean, Polynesia, etc., and the beautiful *M. palma-rosæ*, from the Philippines, being examples. The species of *Muricantha* are like *Chicoreus* in form, but with numerous varices. The west coast of Tropical America and West Africa produce some of the largest and handsomest species. Of all the group, perhaps none surpass in beauty of construction some of the forms of *Pteronotus*; *M. lobbeckei*, from the China Sea, which is of a uniform delicate rose-pink tint, and ornamented with elegant fluted frill-like varices, being pre-eminently beautiful. There are several other groups, containing a number of species of considerable interest, which cannot be further referred to in this account. Some mention, however, must be made of the dye which can be extracted from the animals of this family. Species of *Murex* and probably of *Purpura*—a genus referred to subsequently—were both employed in ancient times in the manufacture of the Tyrian purple. The dye was obtained from a white vein at the upper part of the neck of the mollusc. When first extracted, it is of the colour and consistency of cream, but subsequently changes, on exposure to light, to the deep purple tint. The common British *Purpura lapillus* affords similar dye. Its scarcity and the use of cochineal, and other dyes, render it valueless as a commercial product. *Murex erinaceus*, the only British species, is common on oyster-beds, to which it is destructive. All the forms yet referred to have a somewhat roundish or ovate operculum, with the nucleus terminal or subterminal, whereas in those which follow (*Purpurinæ*) it is lateral. All the members of the genus *Purpura* are furnished with strong, heavy shells, suitable for protecting the inhabitants from the rough usage of the sea upon the rocky shores they mostly inhabit. They range from the Arctic to the Antarctic regions, the handsomest species coming from tropical seas. The fry of several species are pelagic, and swim at the surface of the water.

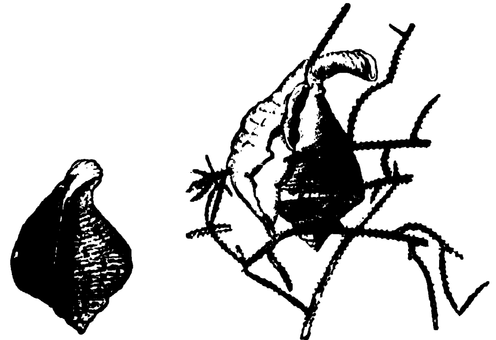


ANIMAL OF *Murex*. *b*, Gill; *b'*, Osphradium, or olfactory organ; *p*, Purple-gland.

Like the murices, these molluscs are devourers of Bivalves. The annexed illustration represents the egg-capsules of the common British *P. lapillus*. The animal and shell of *Acanthina* are similar to those of *Purpura*, but the outer lip of the aperture is furnished at the anterior end with a more or less prolonged conical tooth or prong. *Rapana*, *Concholepas*, and *Sistrum* are other nearly allied forms. The members of the family *Coralliophilidæ* resemble the purpuras, but are characterised by the want of a radula, and their singular mode of life, dwelling either in or upon corals. *Rhizochilus* in early life is like the young of *Purpura*, but subsequently it attaches itself to barked corals (*Antipathes*), living a prisoner's life, immured within its own shell. It prolongs the lips of the shell around the stems of the coral, completely closing the aperture, with the exception of the siphonal end, which it extends into a distinct tube, serving to carry both water to the gill and food to the mouth. What the nature of its nourishment may be—possibly derived from the *Antipathes* itself—and what may be the reason of this self-immurement, are problems to be solved. *Coralliophila madreporarum* attaches itself to corals; other species live a more active life, crawling over the surface of the coral. Several are tinted with lilac, and have purple apertures; others, however, are entirely white. *Leptoconchus* and *Magilus* are both dwellers in coral. The former lives in crypts excavated in brain-stone corals, and resembles, as regards the shell, the young state of the latter. *Magilus* affects coral-reefs, and is remarkable for the great alteration which takes place in the course of its career. At first it assumes the form of an ordinary spiral shell, and takes up its abode within the crevices of growing coral. The coral slowly advances around the shell, and would soon enclose it, if the mollusc were not provided with some means of defeating this. The creature prolongs the lips of its aperture into a long, but mostly crooked tube, so as to keep pace with the growth of the coral, and keep the tube open for the free ingress of the water. As the tube increases it becomes too long for the animal; consequently the mollusc fills up the spiral portion, and as much of the tube as is not required. These shells are found in the Red Sea, and the Indian and Pacific Oceans.



EGG-CAPSULES OF *Purpura lapillus*.



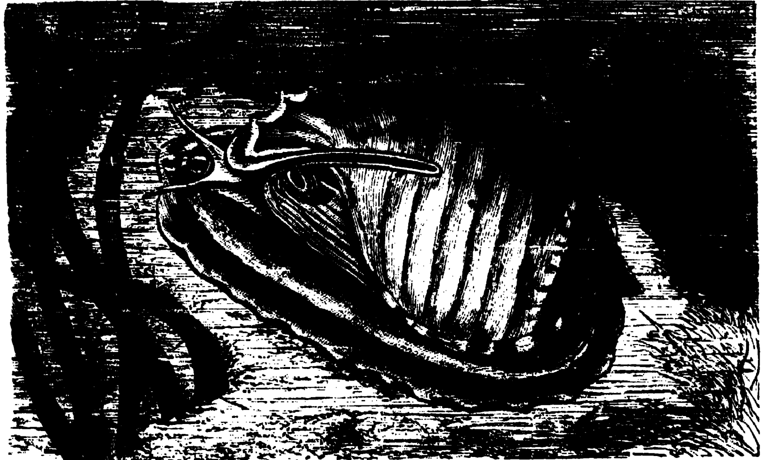
Rhizochilus antipathum. *a*, Young; *b*, Adult.

SECTION TÆNIOGLOSSA.

The majority of the molluscs included in this section of Pectinibranchs are marine forms; although a few families are found in fresh water, while others are terrestrial and air-breathers. Typically, the radula has seven rows of teeth, one central, and three laterals on each side; but there are a few families in which this armature is modified. Sometimes there is only a single lateral on each side; but,

on the contrary, the number of laterals occasionally reaches five a side. They are curved and claw-like in some groups, but in others merely have serrated edges. Forty-two families are included in this section; but the limits of this work admit only of an account of some of the more important. The animals of one group are provided with shells, which either have a distinct, prolonged anterior canal, or else the aperture is more or less deeply notched at the base. In another group the mouth is entire, without notch or siphonal canal. Some have a retractile proboscis, like murices and whelks; others have a longer or shorter muzzle or rostrum, which is somewhat contractile.

The first family is that of the tritons (*Tritonidæ*), many of which possess large, handsome shells, exhibiting strengthening ridges (or former lips) at intervals upon the spire. The animal has a shortish foot, a large head projecting between the slender, pointed tentacles, supporting the eyes at the sides or at the base, and a horny operculum. *Triton* and *Ranella* are the two genera constituting this family. In the former, the large *T. tritonis*, the war-trumpet of the South-Sea islanders, is the typical kind. It attains more than a foot in length; and when the top of the spire is broken or ground off, a booming note can be produced. A similar species (*T. nodiferus*) lives in the Mediterranean, and was employed in the same way by the Romans. Most of the tritons are covered with a conspicuous periostracum, and in some cases this is beset with short hairs or bristles. The form of the shells is very variable in the different subgenera, but all exhibit the character of periodic ridges. The shells in the genus *Ranella* are very like *Triton*; but the typical forms possess a posterior canal or sinus at the upper part of the aperture, which is not met with in the latter. The varices are mostly in two continuous series, one up each side of the spire. The species of this and the preceding genus are not very numerous—hardly two hundred altogether—and are chiefly inhabitants of warm climates. A few range as far north as Alaska and Japan; others occur on the shores of Patagonia, the Cape of Good Hope, Amsterdam Island, and New Zealand. Two species—*T. nodiferus* and *T. cutaceus*—have been occasionally obtained from the Channel Islands. Like *Strombus*, this group of molluscs appear to be great scavengers. M. Vélain, when at Amsterdam Island, observed that the dead carcases of seals, left by fishermen on the rocks at low water, were literally covered with lobsters and *Ranella* at the following tide. In the helmet-shells, family *Cassididæ*, the shells develop varices at intervals, like


HELMET-SHELL (*Cassis glauca*).

the tritons, but they are broader, more globose, and have shorter spires. The aperture is more or less dentate on each side, and the siphonal canal short, and sharply recurved. Upon the columellar side the animal deposits a strong shelly callosity, which in some species is enormous, and unites with the outer lip above. The animal closely resembles that of *Triton*; its dentition is similar, but the opercula in this family are peculiar, having a lateral nucleus, and often being rayed like an expanded fan. The shells of some species consist of different-coloured layers, and are made use of for carving shell-cameos, in order that the subject may stand out in relief upon a differently-coloured ground. This family includes the genus *Cassis* and its subgenera, and the genera *Morio* and *Lambidium*. Nearly all the species are from hot regions, but a few occur in Japan and New



TUN-SHELL, *Dolium perdix* (½ nat. size).

Zealand; and the well-known Mediterranean *Morio tyrrhenus* has of late years been dredged living in deep water off the south-west of Ireland.

The tun-shells (*Doliidæ*) are mostly thinnish and of globose form, sometimes of very large size, and always spirally ribbed and grooved. They have no varices, and are without opercula. The foot of the animal is large, and the retractile proboscis long, and furnished with an expanded disc at the end, as in the figured *Dolium perdix*. The shells of the subgenus *Malea*, which have the outer and inner lips strongly dentate, form a connecting link with the *Cassididæ*. Nearly all the species, about fifteen in number, are tropical. Two, however, occur in the Mediterranean, and several in Japan; *Dolium galea*, which occurs off the south of France and other parts of the Mediterranean, has a shell 8 to 10 inches in length, and is the largest gastropod of that region. This mollusc, as well as various species of *Cassididæ* and *Tritonidæ*, are said to secrete sulphuric acid.

The fig-shells (*Pirula*) have an extensive foot, like *Dolium*, but the mantle is largely lobed on each side, and reflexed upon the shell. This is of an elongate pear-shape, with a short spire and a long canal, and has the surface transversely striated or ridged, or more or less cancellated. There are nine recent species belonging to this genus, which is also found fossil in the Chalk and Tertiary deposits. The genus is included in the *Doliidæ*.

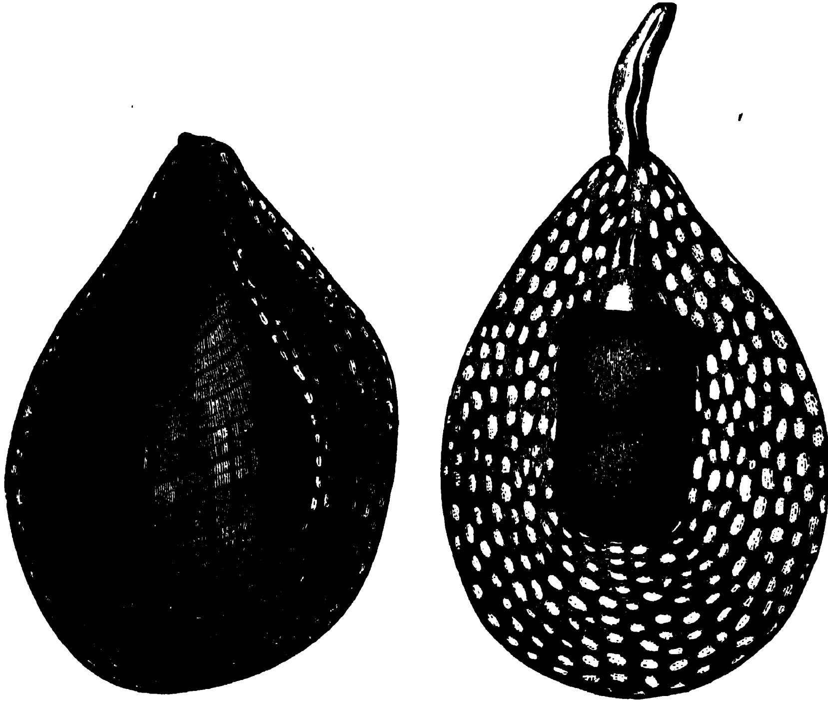


FIG-SHELL (*Pirula ventricosa*), FROM ABOVE AND BENEATH (nat. size).

The cowry, or, more properly, kauri shells (*Cypræidæ*), are so well known that a description is scarcely necessary. They are all formed much after the same pattern, and are almost always coated with a brilliant enamel, caused by the lateral lobes of the mantle being reflexed upon the shell. In the young the shells exhibit a short spire, which in the course of growth becomes entirely or almost concealed. Many of the shells are exceedingly beautiful, and some of the animals are even more brilliantly coloured. The cowries have no operculum, but a large foot, and can retract their bodies entirely within the shell, notwithstanding the narrowness of the aperture. The shells, as is well known, are sold as ornaments, and some of the rarer kinds are greatly prized by collectors. A small yellow species, the money-cowry (*Cypræa moneta*), abundant in some parts of the Indian and Pacific Oceans, is used as coin in India and among the negroes of certain parts of Africa. The orange cowry (*C. aurora*), one of the finest of the group, used to be worn by the chiefs in the Friendly Islands. The cowries, of which nearly two hundred species are known, are found most abundantly in tropical regions, but a few stragglers occur in temperate seas. Only one small and ridged species (*C. europæa*) is found on the British coasts, and about a hundred fossil forms, chiefly Tertiary, are known. The genus *Ovula* is allied to *Cypræa* as

regards the general conformation of the animal, but has a somewhat different radula and shell. It contains several subgenera, the most important being *Radius*, *Ultimus*, and *Calpurnus*. *Radius volva* is perhaps the most remarkable of all the species. Many of them live parasitically upon sea-fans, the shells assuming the



MONEY-COWRIES.

same colour as the bark of the coral. *Pedicularia* and *Erato* also belong to this family, although the shell of the former appears to possess no relationship with its other members.

The wing-shells, or strombs (*Strombidæ*), include some very large species, which when young somewhat resemble a long-spired cone. When mature, however, the outer lip thickens and spreads out, and upon the edge may be developed six, or more, claw-like appendages (*Pterocera*). The aperture is notched anteriorly for the short respiratory siphon, and the outer lip situated near this siphonal notch, and also often posteriorly at its junction with the whorl above. The general form of the shell is shortly or elongately fusiform, or conical. The animals have a well-developed, ringed, contractile proboscis, with the mouth at the end, at the base of which arise two enormous eye-stalks, supporting on their inner side the true, but very small tentacles.

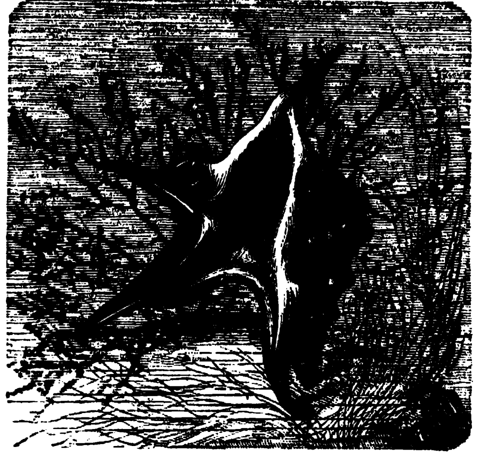


WING-SHELL (*Strombus lentiginosus*).



GLASS SPONGES.

The eyes are situated at the truncate ends of the long, cylindrical stalks, and, like those of the Cephalopods, are more highly organised than in many fishes, having a distinct crystalline lens, with a highly-coloured iris. The foot is unlike that of ordinary gastropods, and not adapted for crawling; being a powerful, muscular organ, so modified as to serve the purpose of a lever in their hopping or leaping mode of progression. The operculum is claw-shaped, and attached to the hinder branch of the foot. These molluscs are great scavengers, and feed upon decomposing animals of any description. About sixty species of *Strombus* have been described, almost exclusively confined to tropical seas. The beautiful pink *S. gigas*, of the West Indies, is brought to Europe in immense numbers, and, when ground to powder, employed in the manufacture of the finer kinds of porcelain. It is also used for cameo-carving, and produces pink pearls. The spider-shells (*Pteroceras*), with the claw-like projections from the outer lip, have already been referred to. The beak-shells (*Rostellaria*) are remarkable for the long, acuminate spire, and the prolonged, slender, anterior rostrum. On the contrary, in *Terebellum*, the last genus of this family, there is no canal whatever, but merely a slight sinus or emargination at the base of the outer lip. Allied to this family are the *Aporrhaiidæ* and *Struthiolariidæ*, the former including some remarkable fossil forms. *Aporrhais pespelecani* is a common British shell, occurring all round the coast, and usually known as the pelican's foot. In the *Cerithiidæ* the shell is typically elongate, and more or less pointed, with a notch or recurved canal at the front part of the aperture, which is rather short. It is generally solid, tubercular, or ribbed, and has no periostracum. The animals are very like the periwinkles, and are provided with a horny operculum. They are vegetable-feeders, very numerous in species, and inhabit both salt and brackish water. Whereas the species of *Cerithium* are all marine, such forms as *Potamides*, *Pyrazus*, and *Cerithidea* occur in brackish marshes, and at the mouths of rivers. The fossil species of this family far exceed the recent, both in point of numbers and



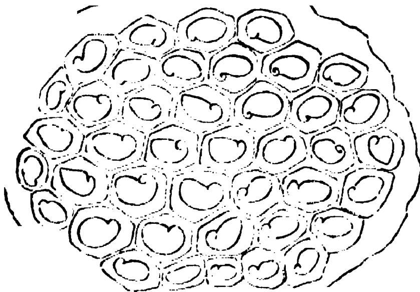
PELICAN'S FOOT (*Aporrhais pes-pelecani*).



WORM-SHELL (*Vermetus lumbricalis*).

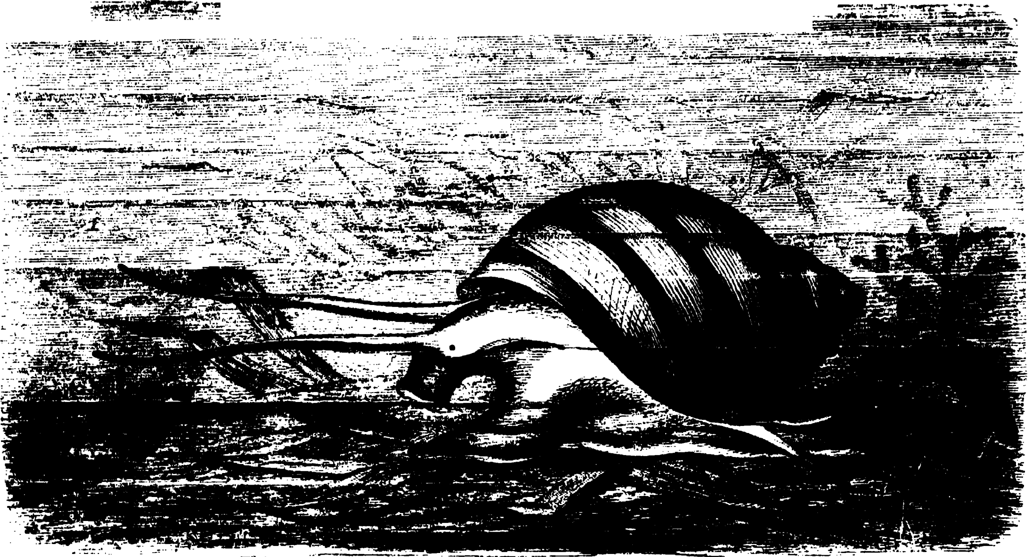
size; *Cerithium giganteum*, an Eocene form, attaining quite a foot and a half in length.

One of the most curious groups of gastropods is that of the worm-shells (*Vermetidæ*), in which the shells might be mistaken for the tubes of marine worms, as they are similarly twisted and attached to stones and other substances in the same way. They are free and spiral in early life, and crawl about like ordinary gastropods, but they afterwards settle down and become stationary for the rest of their existence. In these circumstances, a walking-foot, being of no further use, becomes modified into a mere support of the operculum. The animals are worm-like, with a short proboscis, horny jaws, and radula, and the head supporting two short tentacles, with the eyes at the base. The species are not numerous, and occur chiefly in warm and temperate seas. The members of the extensive family of the *Melaniidæ* are inhabitants of fresh water, and are abundant in all subtropical parts of the globe. The shells are not, as a rule, attractive, being clothed with a dark or olivaceous periostracum. Some are long, slender, and acute, others quite globular. Perhaps the most remarkable form is *Tiphobia horei*, an inhabitant of Lake Tanganyika, in Central Africa. In the typical *Melania* the aperture of the shell is entire, but in some of the other genera, such as *Melanopsis* and *Faunus*, it is distinctly notched in front. The animal is provided with a horny operculum, and many are viviparous. Hundreds of species have been described, but many, as is the case in all fresh-water groups, are distinguished by very slight differences. The *Strepomatidæ*, or *Pleuroceridæ*, are the North American representatives of the *Melaniidæ* of the Eastern Hemisphere, from which they are distinguished by the absence of the marginal mantle-fringes, and in being oviparous in their mode of reproduction. In certain places they abound in such countless numbers as almost to cover the bed of some of the streams in Tennessee and Alabama. About five hundred forms have been recognised. The genus *Io* contains the largest and most striking species of all. They are short, spindle-shaped shells, often with nodose or spinose whorls, and with the aperture prolonged into a distinct anterior canal. They are restricted to certain parts of Virginia and Tennessee. The little sea-snails known as periwinkles (*Littorinidæ*) are dwellers on the shore. They are all vegetarians, and occur in the Arctic and Antarctic regions, as well as in temperate and tropical shores, wherever they can find rocks and stones to crawl upon. Some occur at low water; others live at high-water mark, or where they are only occasionally reached by spring tides. Some ascend the mangrove trees, and have been found hundreds of yards from the sea. Four species of *Littorina* inhabit the English coast, the commonest being the well-known *L. littorea*, which is consumed in such enormous quantities. The periwinkles have horny jaws, and a very long radula, sometimes two or three times as long as the animal itself; and they are all furnished with a horny operculum to protect themselves with, when



SPAWN OF PERIWINKLE (magnified).

retracted within their shells. The spawn of this species is illustrated in the figure. Nearly allied to the last is the genus *Lacuna*, in which the animal has long, slender tentacles, while on the upper part of the foot there are two long appendages, which extend much beyond its pointed extremity. The species illustrated occurs on the British coasts, and, like the periwinkles, feeds upon seaweeds. The so-called staircase-shells (*Solariidæ*) are all formed much upon



HORNED WINKLE, *Lacuna divaricata* (enlarged).

one and the same plan. They are more or less conical, flattened, and umbilicated beneath, and nearly always beautifully sculptured. In *Solarium* the umbilicus is often very wide, and is bordered by a crenulated edge, winding upwards to the apex of the shell, and terminating in a notch upon the aperture. The embryonic shell is sinistral, and in the course of growth becomes turned spire-downwards, and, with the exception of its base, concealed by the succeeding whorls. About twenty species are known, and are chiefly met with in tropical seas. In *Torinia* the shells are more narrowly umbilicated, and not carinate at the margin like *Solariium*, and the operculum is very remarkable, being conical, and consisting of many whorls.

All the molluscs belonging to the *Rissoidæ* are very small. The shells are something like a minute *Littorina*, but they are often longitudinally ribbed, a style of sculpture not met with in the periwinkles. They are found everywhere, and live upon algæ. A large number of species have been described, and doubtless many forms from all parts of the world remain to be discovered. Even upon the English shores between twenty and thirty forms are met with. This family has been divided into a number of genera and subgenera, partly on differences in the soft-parts, and partly upon conchological grounds. The *Hydrobiidæ* are closely allied to the *Rissoidæ*, and may be regarded as their representatives in fresh and brackish water. Like the periwinkles, although



Rissoa.

furnished with gills, they are more or less amphibious, passing part of their time out of the water. Four are British.

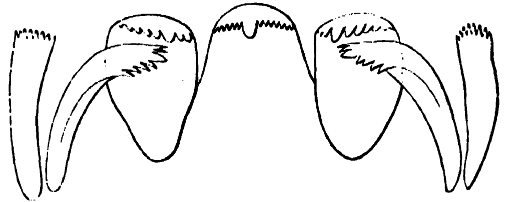
The viviparous pond-snails (*Viviparidæ*) in general appearance are not unlike periwinkles, having a longish contractile rostrum and elongate pointed tentacles with the eyes situated upon short projections at the base. There are two neck-lappets, the right forming a rudimentary respiratory siphon. The foot is broad in front and narrowed behind. The species of *Vivipara*, as their name implies, are viviparous, and the young are brought forth provided with a shell having three rows of bristles, and at once start upon an independent career, like the adult. They are sluggish creatures, and generally live more or less in mud at the



VIVIPAROUS POND-SNAILS, *Vivipara*; male on left, female on right, young (magnified) in front.

bottom of rivers or canals, and feed upon decaying vegetable or animal matter. The North American species form the genera *Melantho* and *Tylotoma*, and most have more solid shells than in *Vivipara*. One of the finest species occurs in Lake Tanganyika, and is remarkable on account of the aperture being somewhat effuse at the base, and in having the outer lip slightly sinuated in the middle. On this account it was at one time placed in the separate genus *Neothauma*, but examination has shown that it does not essentially differ from *Vivipara*. The character of the lingual teeth in this family is shown in the accompanying figure representing a single transverse series. Two species occur in England, one of which (*V. contecta*) is here figured. The *Valvatidæ* comprise a few small molluscs closely allied to the last. They occur in Europe and North America, and are remarkable for protruding a plume-like gill beyond the mouth of the shell, which is somewhat discoid or turbinate in form. *Valvata cristata* and *V.*

piscinalis occur in places throughout the British Isles. The shells of the *Ampullariidæ* are not unlike those of the *Viviparidæ*, but are mostly larger, and rather more globose. They are covered with a shiny, greenish, or olive periostracum, and often ornamented with transverse colour-bands. All are provided with large ovate opercula of concentric growth, which in species from the Western Hemisphere are thin and horny, whereas in the Old World forms they are thickened internally with a shelly layer. Although these shells have entire mouths (holostomatous), without a canal or even a notch in the aperture, the animal is provided with a long respiratory siphon. The species of *Ampullaria* are amphibious, and inhabit marshes in tropical countries. They are provided with both lungs and gills, and breathe both air and water. Professor Semper observes that these molluscs "breathe not only with both gills and lungs, but they do so in regular alternation; for a certain time they inhale air at the surface of the water, forming a hollow elongated tube by incurving the margin of the mantle, so that the hollow surface is closed against the water and open only at the top. When they have thus sucked in a sufficient quantity of air, they reverse the margin of the mantle, opening the tube, into which the water streams." They are capable of living out of the water for a long time, and it has been stated that some specimens kept in Calcutta for five years were alive at the end of that period. South America produces the largest forms, but there are also a few handsome species from Central Africa, Madagascar, India, and the Eastern Archipelago. In the genus *Lanistes*, which occurs only in Africa, the shells are all sinistral, and have horny opercula.



ROW OF TEETH FROM THE RADULA OF *Vivipara* (greatly magnified).

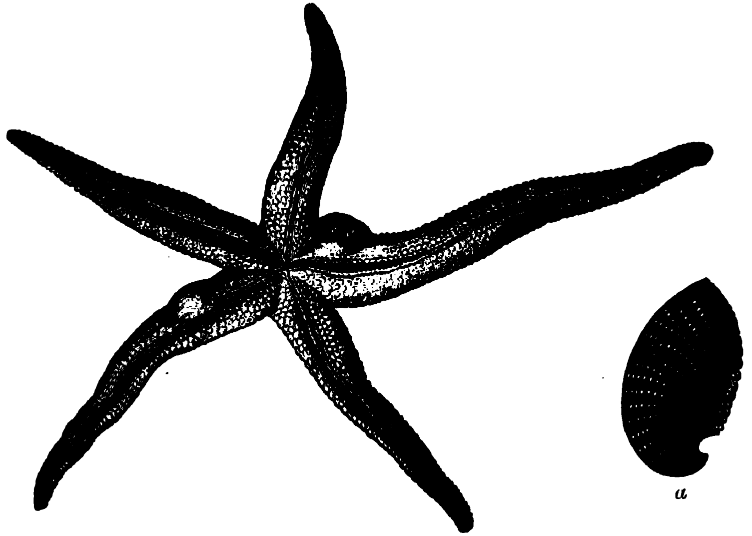
The families *Cyclophoridæ* and *Cyclostomatidæ* comprise a large number of air-breathing land-snails, formerly classed with the Pulmonata. The breathing-organ is not a true lung, like that of the snails and slugs, but a vascular branchial chamber, modified for air-breathing, and open in front, the mantle being free above the nape of the neck. The animals are unisexual, and formed much after the fashion of periwinkles. They have a long rostrum, two contractile tentacles, with the eyes at the base, and the radula has seven rows of teeth, arranged as in *Littorina* and allied genera. Another distinguishing feature is the presence of an operculum, which is possessed by all the species. In the *Cyclophoridæ* this is generally horny, circular, and multispiral, with a central nucleus, whereas in the *Cyclostomatidæ* it is mostly of a shelly texture, and paucispiral. In the latter family the animals have the sole of the foot divided down the middle by a groove, and, when walking, the halves are alternately advanced. The species of these families are numerous, and are principally found in hot climates. A few, however, occur in more temperate regions; two, belonging to distinct genera, being found in Britain. The shells are variable in form, and can only be appreciated by studying a series of specimens or figures. The species are classified in a large number of genera, which, although based on a combination of characters, are mostly distinguishable by differences in the opercula. *Cyclostoma, Otopoma, Chondropoma,*

Choanopoma, *Cistula*, *Tudora*, *Omphalotropis*, are the principal forms of *Cyclostomatidæ*. Some of the handsomest and largest species are found in Madagascar and Mauritius, but some of the West Indian islands are noted for the immense number of species they produce. Among the *Cyclophoridæ*, the most important groups are *Cyclophorus*, *Leptopoma*, *Cyathopoma*, *Pterocyclus*, *Opisthoporus Pupina*, *Cataulus*, and *Megalomastoma*. The minute forms, known as *Opisthostoma* are, perhaps, among the most wonderful structures of the whole family.

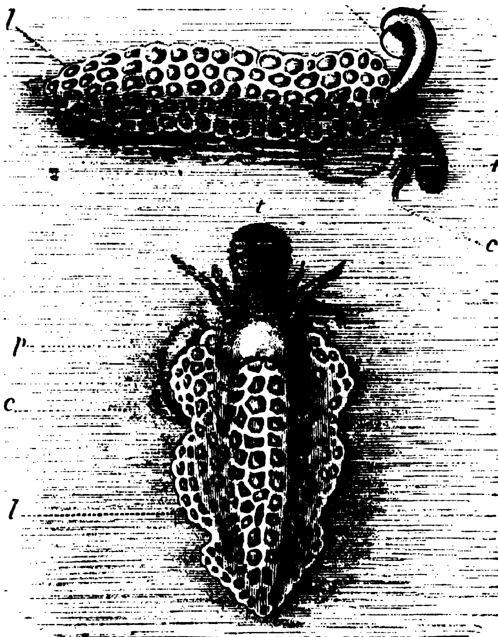
The species comprised in the family *Truncatellidæ* are all small, and live either between tide-marks (*Truncatella*) or upon the land (*Geomelania*). The shells are elongate, and in the young state terminate in a pointed spire, which is subsequently cast off, the shells then assuming a truncate appearance at the top. They have a very peculiar mode of progression, resembling that of the looper caterpillars, the end of the muzzle and the foot being successively advanced. The characteristic feature of the typical genus (*Hipponyx*) of the allied family *Hipponychidæ* is the secretion by the foot of the animal of a shelly plate, which is attached by its outer surface to stones, shells, or other substances. It forms a permanent resting-place for the conical shell, and is attached to the adductor muscle of the animal. In some of the fossil species these lower plates are so greatly developed that they were at one time regarded as bivalved shells. *Amalthea* has a shell very like *Hipponyx*; it does not form a basal plate, but excavates a hole in the surface of other shells to fit the aperture of its own.

The members of the family *Calyptræidæ* are limpet-like in their mode of life, living attached to stones, shells, etc. The shells are more or less conical, but spiral towards the apex. The interior is either simple, as in *Capulus*, parted off by a transverse septum (*Crepidula*), or a cup-like process, varying in form, is developed in the upper part (*Crucibulum*). The animals have a short proboscis, two slender tentacles with the eyes near the base, and the mouth furnished with a radula bearing a prolonged tusk, like the *Naticidæ*. Being permanently located, it becomes a matter of conjecture what they feed upon. Possibly the minute forms of life which abound in the sea form their staple nourishment. The various genera are for the most part recognisable by differences in the shell, the form of the internal septum and "cup" furnishing good characters. The number of living forms is considerable, and they are found in all seas. Two occur on the British coast,—*Calyptræa chinensis* and *Capulus hungaricus*,—and a third, *Crepidula fornicata*, supposed to have been imported with American oysters, is becoming an established resident on the Essex coast. Closely allied to *Capulus* is *Thyca crystallina*, which lives parasitic upon star-fish at Mauritius and in other parts of the Indian Ocean. In the family *Xenophoridæ* are contained a remarkable group of molluscs known as carrier-shells, so-called from the instinctive habit some of them possess of carrying about with them shells, stones, and other substances, which they cement to the exterior of their own trochiform shells. Doubtless this concealment is to some extent protective. The animals bear some resemblance to *Strombus*, but their eyes are very inferior, and placed at the base of the tentacles. They are furnished with opercula, which, however, are more like those of *Purpura* than *Strombus*. They resemble the latter in their leaping and scrambling mode of progression, not gliding along on the sole of the foot

like most other gastropods. In the family of the naticas (*Naticidæ*), which is numerous in both recent and fossil species, the shells are more or less globular or ear-shaped, and the animals remarkable for the enormous development of the foot, which is used as a plough to drive through the sand in search of other molluscs—mostly bivalves —upon which they feed. The foot is so large as almost to conceal the shell, and the front part of it (the *propodium*) hides the head, which has no visible eyes. The shells are quite closed in some of the groups by a paucispiral operculum, which is either horny or shelly. Naticas are found in all parts of the globe. The largest living species (*Lunatia heros*) occurs on the eastern coast of North America, but some of the more highly-coloured forms are found in tropical seas. About half a dozen species occur in Britain. The spawn-cases are curious objects, resembling a broad sandy strap coiled round like a horseshoe.



STARFISH WITH *Thyca*; *a*, Shell of latter enlarged.



VIOLET SEA-SNAIL (*Ianthina*) WITH ITS FLOAT.

b, A bubble, drawn, somewhat too large, about to be joined to the anterior end of the float; *c*, Shell; *l*, Float; *p*, Foot; *t*, Head.

SECTION PTENOGLOSSA.

In this unimportant group of Pectinibranchs—which includes only the families *Ianthinidæ* and *Scalariidæ*—the radula consists of numerous rows of pointed teeth, arranged in cross series forming an angle in the middle. There is no central or rhachidian tooth. The violet sea-snails (*Ianthinidæ*) have thin trochiform shells, adapted for a pelagic life. These are mostly of a violet colour, the base or underside, which is turned upwards and exposed to the light when the animal is swimming at the surface of the sea, being more deeply tinted than the rest of the

shell. The most interesting feature in connection with these oceanic snails is the curious float which they construct to support their egg-capsules. It is a sort of gelatinous raft, enclosing air-bubbles which cause it to float at the surface; and is attached to the foot, the egg-capsules being suspended from its under surface. The violet-snails feed on various kinds of jelly-fish, and occur in shoals on the high seas. Being unable to sink, so long as they are in connection with their floats, they thus escape from storms and are often cast ashore in immense numbers. The species are few, and, like other pelagic forms, are widely distributed. *Recluzia*, the only other genus in the family, has a pale brownish shell with a longer spire than *Ianthina*. It likewise forms a raft. The shells of the wentle-traps (*Scalariidæ*) are mostly white, and formed on the same plan. The spire is more or less elevated, the aperture entire, and the whorls are ornamented with a succession of ribs or varices which give the shells a pretty appearance. The animals are carnivorous. More than one hundred and fifty species are known, and they occur in all seas, as far north as Greenland. Four inhabit the British shores, one (*Scalaria communis*) being the most prettily coloured shell of the genus. *S. pretiosa*, a native of the China Seas, is the largest member. It was formerly of value, between twenty and thirty pounds having been given for a specimen.

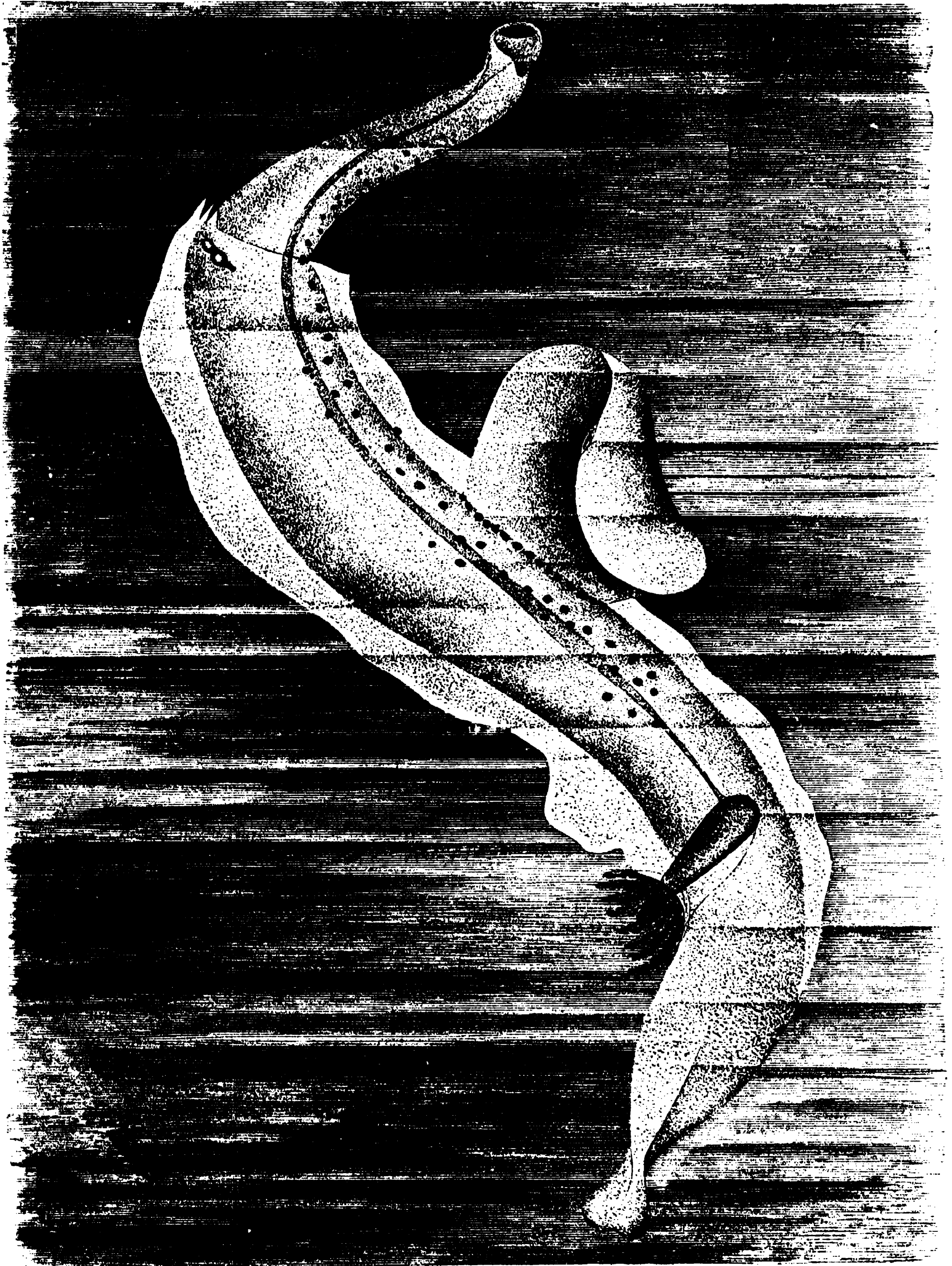
SECTION GYMNOGLOSSA.

This, the last of the five sections into which the Pectinibranchs are divided, is characterised by the absence of the radula. Two families are included in it, namely, the *Eulimidæ* and *Pyramidellidæ*. The former have white, polished, pointed shells, with an ovate aperture, closed by a thin, horny operculum. Many of them are curved in the course of growth. Some are known to live commensally or parasitically upon or within various species of holothurians. *Stylifer*, which lives in or upon star-fish and sea-urchins, usually has a thinner and more glassy shell than *Eulima*, and has no operculum. A few species are found in Britain, but the family is more numerous in warmer latitudes. In the second family the majority of the species are very small; and while all are dextral in the adult state, the young shells are remarkable for having the nuclear whorls sinistral. Some are longitudinally plicate, others transversely ridged, cancellated, or smooth, and the columella often exhibits one or more plaits or denticles, which are conspicuous in some and almost obsolete in others. The diversity of form and surface ornamentation, in the very numerous species of this and many other families, can only be seen in a collection of specimens, or a good series of illustrations. About forty species are British, none of which belong to the typical *Pyramidella*.

Suborder **Heteropoda**.

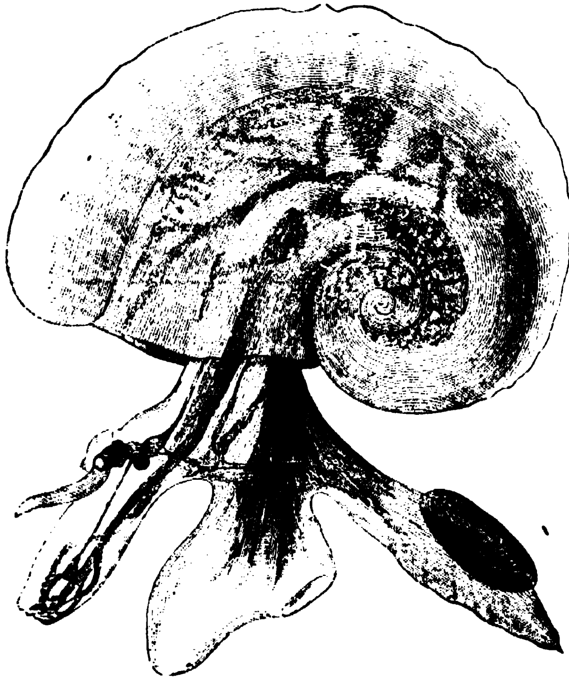
This group is regarded by some systematists as a distinct order, and by others merely as a division of the Pectinibranchia; and it sometimes appears under the name of Nucleobranchiata. It includes gastropods modified for a pelagic life. The foot, in place of being adapted for crawling, is laterally compressed, and serves the purpose of a fin, and is also used as a means of attachment to the prey or any floating substances. The Heteropods are found on the high seas in every warm part of the globe. They have distinct sexes, are predatory in their habits, feeding

upon all sorts of pelagic life which surrounds them. They have no jaws, but are furnished with a radula with seven rows of teeth like the tænioglossate gastropods. Some have shells capable of containing the retracted animal; in others, the shell



A PELAGIC HETEROPOD, *Pterotrachea* (nat. size).

only serves the purpose of protecting the vital organs, and in some forms it is altogether wanting. The Heteropods may be divided into two families, *Pterotracheidæ* and *Atlantidæ*. The former includes the genera *Pterotrachea, Firoloida, Cardiapoda, Carinaria*, and *Pterosoma*; a species of the typical genus being shown on the preceding page. It is a transparent gelatinous creature. The gills are exposed near the tail, and the fin-like foot, with the minute sucker upon the edge, is seen on the opposite side. The sucker is smaller in the females than the males. About sixteen species are more or less determinable. *Firoloida* has no gill and the visceral nucleus is situated at the posterior end of the body, with scarcely any caudal prolongation beyond it. The males are provided with two slender tentacles in front of the eyes, the females being without these appendages, and the fin-sucker, as in *Pterotrachea*, is also larger in the males. Neither this genus nor the preceding has any shell. In the allied *Cardiapoda* the nucleus is pedunculated, and partly protected by a minute glassy spiral shell. The most interesting of this family is *Carinaria*, on account of its beautiful vitreous cap-shaped shell; the animal being rather like that of *Cardiopoda*. The commonest species is the well-known Mediterranean *C. lamarcki*, but the largest is *C. cristata* from the Indian and China seas. The embryonic shell of *Carinaria* is spirally coiled like a snail-shell, and bears no resemblance to the beautiful adult structure. The latter at one time was so rare that one hundred pounds is said to have been given for a specimen. Even now, large and perfect shells are rare. The *Atlantidæ* contains two genera, *Atlanta* and *Oxygyrus*. The shells are small, compressed, and spirally coiled, of a glassy texture, and capable of containing the animal. The gills are situated in a dorsal cavity of the mantle, and the foot is trilobed, one portion of it supporting a minute, subtrigonal operculum. About twenty species are recognisable, *Oxygyrus* being represented by only two. They abound in the warmer parts of the Atlantic, Indian, and Pacific Oceans.



Atlanta peroni (magnified).

Suborder **Scutibranchiata.**

The great feature of these animals is the absence of certain functional organs in the different sexes; the radula being also of a peculiar type, and armed with several central and lateral teeth. The two sections of the suborder, Rhipidoglossa and Docoglossa, are based upon differences in the radula. In the

former there are nearly always several central teeth, one lateral and many small marginals; and in the latter the typical radula, which is very long, has one or two pairs of central teeth, a large single lateral on each side, with a few small marginals. The first family (*Helicenidæ*) forms a numerous group of small operculated land-shells, which abound in the West Indies and the islands of the Pacific and Indian Oceans. A few occur in Australia, China, and Central and South America, but they are unknown in Europe or Africa. Many are attractively coloured, and a few remarkable for the serrate keel at the periphery. Next come the nerites (*Neritidæ*), all of which are aquatic, and feed upon vegetable substances. In *Nerita* the shells are globular, and strongly made to resist the action of the waves, for these molluscs are inhabitants of the seashore. They are furnished with a shelly operculum, which has a process jutting out from beneath and fitting under the toothed or wrinkled columellar lip when the mollusc retires within its shell. The species of *Neritina* have mostly thinner shells, especially those which inhabit fresh-water streams, and are also furnished with an operculum, like *Nerita*, but thinner. The pillar-lip is thin and smooth, or only finely dentate at the edge. In the section *Clithon* the shells are beset with a coronet of spines. The most remarkable form of that group is *N. longispina*, from mountain streams in the Mauritius. About two hundred species of *Neritina* are known, which abound in intertropical regions and the islands of the Pacific. One small species, *N. fluviatilis*, occurs in Britain, where it is found in slow rivers with a stony or gravelly bottom, and is often coated with a calcareous deposit. The animal has a stout proboscis, long, pointed tentacles, and eyes placed upon short stumps at the base of the tentacles. The species of *Septaria* are somewhat limpet-like, but with the apex of the shell bent towards one end. They also have an operculum of a peculiar type, partly embedded in the foot. The species are principally met with in tropical islands. Among the fossil forms, *Velates conoideus* is interesting on account of its exceptional mode of growth. The top-shells (*Turbinidæ*), like those of the next family, have one characteristic in common, namely, a brilliantly pearly layer beneath the outer calcareous surface. The animals of both groups are vegetable-feeders and much alike, and are peculiar on account of the tentacular processes on the sides of the foot. In the *Trochidæ* the operculum is horny, circular, multispiral, and with a central nucleus; in the *Turbinidæ*, it is thickened with an outer shelly layer, consists of fewer whorls, and often has the nucleus excentric. The latter family is typified by the genus *Turbo*, which has been divided into a number of groups or subgenera on account of differences in this structure. The species are fairly numerous in tropical seas, but rare in more temperate regions. Of the allied genus *Phasianella* only one species (*P. pullus*) reaches the British shores. The *Trochidæ* have a wider range, are far more numerous, and occur everywhere from the Arctic to the Antarctic circles. The beauty of sculpture and coloration of many of the species of the typical genus *Trochus* is beyond description, and can only be appreciated by an examination of the shells themselves. Most forms are littoral, or inhabitants of shallow water, but a few, and these among the most beautiful, have been dredged at enormous depths. Nearly twenty different species occur around the British coast, and some of them are extremely elegant in

FRESHWATER NERITE, *Neritina* (nat. size).

form and structure. The family *Delphinulidæ* in many respects resembles the *Trochidæ*, and is represented only by the single tropical genus *Delphinula*. The ormers (*Haliotidæ*), although few in number, form an important family, on account of the economic value of the beautiful pearly shells which are employed in inlaying. They are ear-shaped, depressed, with a very small spire, and the last whorl, which practically contains the entire animal, correspondingly large, and pierced with a series of holes commencing at the spire and extending to the front margin, in a line subparallel with the left side. The outer surface is calcareous, and often beautifully sculptured and coloured, but the interior is lined with the most brilliant pearl. The holes in the shell admit water to the gills through a slit in the mantle beneath, and on the edges of the slit there are three tentacular processes which the animal passes through certain perforations. *Haliotis*, like the limpets, has a large foot, adapted for adhering to rocks. Some of the larger forms hold on with such tenacity, that it is impossible to remove them without damaging the shells, except with the aid of hot water. The genus is most abundantly represented in Japan, California, and Australia; but is also met with in New Zealand, the Philippine Islands, Oceania, some parts of the Indian Ocean, and round the African coast, while one species (*H. tuberculata*) ranges as far north as the Channel Islands. They are locally known as ormers, and are consumed in considerable quantities. When properly prepared and cooked, they make a savoury dish. It is worthy of notice that *Haliotis* does not inhabit the South American coasts, nor is it found on the Atlantic side of North America. Until some fifty years ago, the typical genus of the family *Pleurotomariidæ* was supposed to be extinct. Four recent forms are now known, one from Japan, one Moluccan, and two West Indian. Two of these are larger than any of the extinct species. *Pleurotomaria* has a trochiform, discoid, or globose shell, pearly within, with a more or less deep slit in the outer lip of the aperture; the latter being the characteristic feature of the group. It has existed since the Palæozoic epoch. In *Trochotoma*, an allied genus, there is a hole behind the lip in place of the slit, and *Polytremaria* exhibits a whole series of perforations. The anatomy of *Pleurotomaria* shows that it has close relationship with *Haliotis*. Like *Trochus*, it is furnished with a horny spiral operculum. A magnificent specimen of *P. adamsoniana* is exhibited in the shell-gallery at the Natural History Museum. *Scissurella* is another genus of this family, containing a number of very minute shells with a slit in the lip like *Pleurotomaria*; *S. crispata* being a pretty little mollusc found in Britain. The members of the so-called key-hole limpets (*Fissurellidæ*) mostly have shells like those of the limpets in form, but either perforated at the apex, as in *Fissurella*, slit at the front margin (*Emarginula*), or

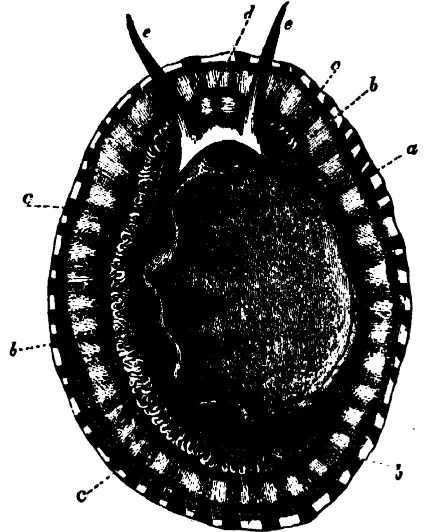


DOLPHIN-SHELL, *Delphinula laciniata* (nat. size).

with a hole between the front edge and the apex (*Rimula*, *Puncturella*). In *Scutum* the shell is less conical, and more elongate, and only very faintly sinuated at the front margin. It is white, and almost wholly concealed beneath the mantle. The holes and slits in these shells serve excretory purposes. The animals are remarkable for their two symmetrical gills, and certain points in their internal anatomy, which offer some resemblance to the bivalves. More than a hundred species of *Fissurella* are known from all seas, except the Arctic. The west coast of South America produces some of the handsomest kinds; but the giant of the genus, *F.* (*Lucapina*) *crenulata* inhabits the shores of California.

SECTION DOCOGLOSSA.

The second group of Scutibranchs comprises the families *Acmæidæ*, *Patellidæ*, and *Lepetidæ*, all being limpet-like molluscs, with a peculiar form of dentition, as already described. The shells of these families are alike in construction, but the animals differ essentially in their respiratory organs. In *Acmæa* there is a single branchial plume, or ctenidium, over the neck; in *Patella* the gills are arranged in almost a circle around the foot; and in *Lepeta* the gill is entirely wanting. In addition to these differences the radula affords further distinguishing characters. Limpets are generally attached to stones and rocks, but when the tide is up they quit their resting-place in quest of food, which consists of various kinds of Algæ. As the tide ebbs they creep home again to the spot which each appropriates as its own location. The common limpet is one of the molluscs eaten on certain parts of the British coasts. With regard to the tenacity with which the limpet holds on, experiments have been made showing that a force of sixty-two lbs., or one thousand nine hundred and eighty-four times its own weight, is required to detach it from the rock.



UNDER SURFACE OF LIMPET.
a, Foot; *b*, Mantle; *c*, Gills; *d*, Mouth; *e*, Tentacles.

EDGAR A. SMITH.

CHAPTER XI.

MOLLUSCS,—*concluded.*

CHITONS TOOTH-SHELLS, AND BIVALVES,—Classes **Amphineura, Scaphopoda, and Pelecypoda.**

THE CHITON GROUP,—Class **Amphineura.**

THE Molluscs included in this class may be regarded as aberrant gastropods, differing from ordinary forms in their symmetrical conformation, having the mouth and excretal orifice at the two extremities of the body, and the tissues of the mantle more or less spiculose. The symmetry which characterises the external parts also extends to the internal organisation. The group is divided into the two orders Polyplacophora and Aplacophora; and is regarded by some authors, and perhaps correctly, merely as an order of Gastropoda, and not forming a distinct class.

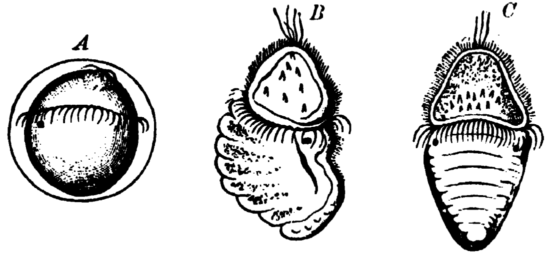
CHITONS,—Order POLYPLACOPHORA.

The well-known chitons (*Chitonidæ*) are the only forms included in this order, and are externally recognised by their shells consisting of eight separate pieces or valves, as they are termed, which are arranged over the back, and connected at the sides by the tough margin of the mantle in which they are embedded. In most cases the valves are close together, extend right across the back, and are exposed; but in some genera they are far apart (*Cryptoplax*), and in others entirely covered by the mantle (*Cryptochiton*). The foot occupies the entire ventral surface of the body, and the mantle covers the upper surface, extending laterally beyond the shell. This portion is known as the girdle, and is nearly always covered with spines, scales, or spicules, which, to some extent, are

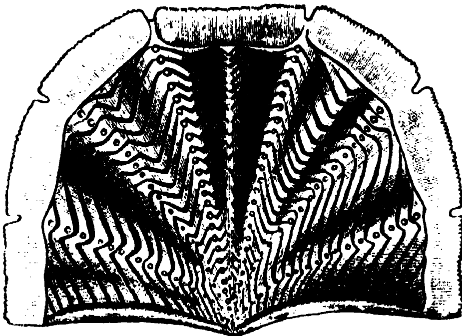


COMMON CHITON (*Chiton squamosus*).

characteristic of the different groups into which the *Chitonidæ* have been divided. The gills are placed on each side between the mantle and the foot, and vary in length. Adult chitons have neither eyes in their head nor tentacles, but the mouth is provided with a long radula, the teeth of which are arranged in a very peculiar complicated manner. The chitons are bisexual, but, like the limpets, destitute of certain functional organs. In the early stages the young chiton bears no resemblance whatever to its parent. This can be appreciated by observing the accompanying figures illustrating three stages in the development of *Chiton marginatus*, one of the dozen species found on the British coasts. The embryo (*A*) is a spherical body, $\frac{1}{31}$ of an inch in diameter, divided into two unequal parts, the dividing line being marked by a row of cilia, and a tuft of similar cilia being situated at the vertex of the smaller half. The eyes are visible upon the lower portion below the cilia. In a later stage (*B* and *C*) the division of the back into eight sections is remarkable and unique in the Mollusca. At this stage the foot begins to develop, the forepart of the animal being ciliated. In later stages of the development the eyes and cilia disappear, the forepart shrinks up into the ridge surrounding the mouth, and the back develops the eight shelly plates. It has already been stated that the adult *Chiton* has no eyes. This is only true as regards the head of the mollusc, for Moseley made the discovery that certain forms have the shell studded with eyes, of which as many as eleven to twelve thousand sometimes exist in a single individual. They are not unlike those already referred to as present on the back of *Onchidium*. Chitons live principally on rocks and under stones at low water, or at moderate depths, but a few have been obtained as low down as two thousand three hundred fathoms. They are all marine, very sluggish in their movements, and, if disturbed from their resting-place, roll themselves up into a ball like a wood-louse. The number of recent species is considerable, and they appear to range all over the globe. Fossil remains of certain forms have been found in most geological periods, since the Silurian.



DIFFERENT STAGES OF THE LARVA OF CHITON (magnified).


EYED CHITON (*Schizochiton incisus*). Anterior valve, with six rows of eyes (enlarged).

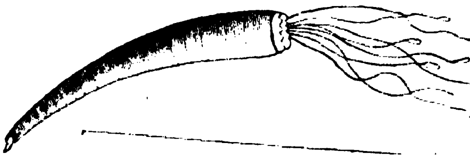
Order Aplacophora.

The molluscs of this order are somewhat worm-like, with a mantle enclosing the entire body, but not secreting a shell, and more or less studded with spicules. They are related to the chitons by certain points in their anatomy, especially with

regard to the disposition of the nervous system. The respiratory organs, when present, are terminal and placed within the anal cloaca. In most of the forms the foot is reduced to a mere longitudinal groove, and does not appear adapted for a locomotive organ. The number of known species is limited. They occur at moderate to abyssal depths in the Arctic and Atlantic Oceans, from the Barents Sea to the coast of Spain. Two families constitute this order, namely, *Chætodermatidæ* and *Neomeniidæ.* The former contains but a single genus, *Chætoderma.* This degraded mollusc, at one time placed among the Gephyrean worms, has an elongate worm-like form, with an inflation at both ends. The mouth is terminal, and armed with only a single tooth—a poor representative of the molluscan radula. The pedal groove is wanting, and the sexes are separate. The only known species—about an inch in length—occurs under stones on the shores of Norway, but has also been dredged in deep water off the coast. The *Neomeniidæ* comprise the genera *Neomenia, Proneomenia, Lepidomenia, Ismenia, Paramenia,* and *Dondersia. Neomenia,* which has been found off the west of Scotland, ranges from Scandinavia to the Mediterranean, and is the best known. *N. carinata* is about an inch long, rather compressed laterally, curved longitudinally, with the back keeled and the ventral side with a narrow foot-groove, extending the greater part of its length. The mouth is unarmed with a radula, and the sexes are united in each individual.

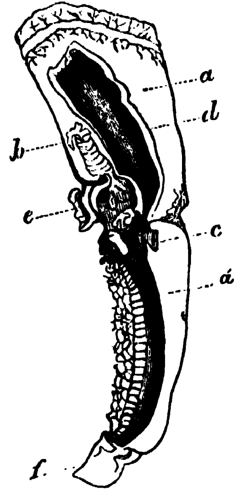
The Tooth-Shells,—Class **Scaphopoda.**

Everybody knows the tooth-shells, resembling in miniature the elephant's tusks, and often found on the sandy shores of England. They are scientifically known as *Dentaliidæ,* and in former times were associated with the marine worms, their shells bearing a strong resemblance to the tubes of certain annelids. They are more or less elongate, nearly always slightly curved, and are bisexual. The head is rudimentary, and in this respect the scaphopods resemble the bivalves. They have no tentacles, eyes, or heart, and the organs of respiration and circulation are rudimentary. At the anterior end of the animal is situated the foot, which is not a creeping disc, but adapted, like that of some bivalves, for burrowing in sand and mud, in which they live and obtain their food, consisting of diatoms and foraminifera. They are said to capture these minute organisms by means of a number of long contractile filaments with expanded extremities (*tentacula* or *captacula*) which are situated near the mouth, which is armed with a radula, and surrounded by labial palpi. The shell is cylindrical, usually somewhat tapering posteriorly, open at both ends, and generally white. A few species, however, are of a greenish tint, and others are pinkish. They are smooth, longitudinally striated and ridged, mostly circular in section, but a few are angular, compressed, and otherwise irregular as regards form. Some are simple at the narrow end; but others exhibit a more or less elongate notch or slit on the ventral or convex side. In some species of *Dentalium* the end has several notches,



COMMON TOOTH-SHELL, *Dentalium vulgare* (nat. size).

and in *Schizodentulium* a series of holes takes the place of a ventral slit. Fossil tooth-shells are numerous from the Devonian epoch upwards, but are most abundant in the Tertiaries. The living forms, of which about a hundred have been described, occur in all parts of the globe, and have been dredged at the greatest depths, although they are probably most abundant in a few fathoms.

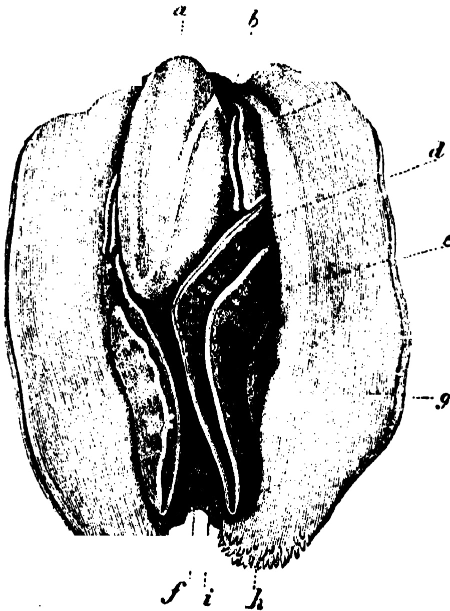


SECTION OF ANIMAL OF *Dentalium* (enlarged).

a, Front mantle-cavity; *á*, Hinder mantle-cavity; *b*, Mouth process; *c*, Anal opening; *d*, Foot-cavity; *e*, Tentacle supports; *f*, Posterior end.

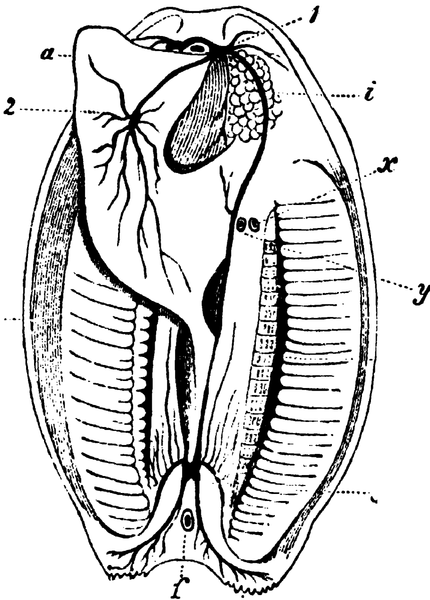
THE BIVALVES,—Class **Pelecypoda.**

This great division includes all forms which secrete a bivalved shell, like the oyster, cockle, and mussel. The Pelecypods offer a different type of organisation from that prevailing in the other classes. The absence of a head, and the bilateral symmetry of the animal, enclosed within a bivalved shell, are characteristic of the class. The mantle is divided into two similar lobes (*g*), right and left, forming a flap on either side of the body, to which it is connected at the upper part beneath the hinge-line of the shell. It is usually very thin, excepting at the edges, which are sometimes double or even threefold. In some genera the edges of the two lobes are free or unconnected at any point excepting at the dorsal attachment, in others they are joined in one or more places, leaving orifices for the protrusion of the foot (*a*) in front, and for the entrance of the water to the gills (*d*, *e*), and for the extrusion of waste and other matter at the posterior end (*f*). The mantle at this posterior opening is often considerably produced, forming one or two distinct tubes or siphons (*h*), which vary considerably in length in different groups, equalling in some instances several times the length of the shell. The extreme development of these siphons obtains in *Teredo*, where they constitute the principal mass of the animal. Some pelecypods appear to be all foot, this member being enormously developed in the razor-shells (*Solen*), for example. In others it assumes smaller dimensions, or it may be absent, as in the oyster. It is used either as a means of locomotion, or for burrowing in sand or mud, or perforating rocks, wood, and other substances; its form consequently being very variable. The mouth (*b*) is situated at the anterior end of the body, at the upper front part of the foot, forming a simple transverse aperture. The



SOFT-PARTS OF RIVER-MUSSEL (*Anodonta*).

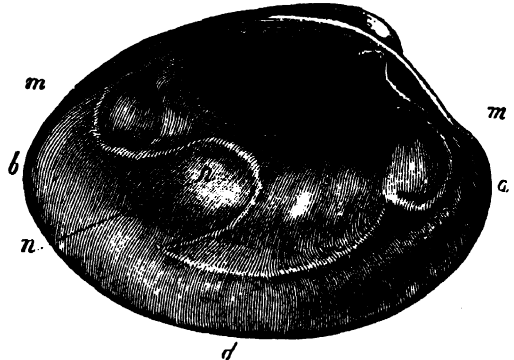
lips, upper and lower, are usually prolonged on each side into two lobes (*c*), or labial palpi. These vary in form, but are mostly triangular. In some groups they are very large (*Tellinidæ*), but in others they are practically wanting. The mouth is not armed with jaws or radula, for in creatures which never prey upon other animals, or go about seeking their food, such structures would be useless. Bivalves obtain their food—consisting of microscopic organisms—in the course of respiration. Whatever is carried in by the inflowing current is collected on the gills, and then conveyed by the palpi to the mouth. The leaf-like gills (*d*, *e*) are arranged on each side of the body, and enclosed by the mantle. Each gill is partly attached by its upper or dorsal margin. This gives rise to two rows of hollow filaments, which are in a few cases simple and disposed in opposite directions, but are generally parallel with one another and directed towards the ventral side, with the filaments long and refolded upon themselves, so that each row forms a double lamella. These filaments are united one to another by cilia. The gills and the inner surface of the mantle-cavity are covered with microscopic cilia, which through their vibratile motion produce the currents of water necessary for respiration. The water generally flows into the pallial cavity at the posterior ventral side, and there is filtered through the gills, passing out again posteriorly through the anal opening. The nervous system consists of three pairs of ganglia, a cerebral or supraœsophageal, a pedal, and a visceral pair. The cerebral ganglia (1) are mostly placed above the œsophagus, the pedal pair (2), as their name implies, within the foot, and the last pair (3) are situated in front of or just beneath the posterior adductor muscle.



ANATOMY OF RIVER-MUSSEL.

Most pelecypods are endowed with the senses of touch, smell, and hearing, and some are provided with eyes. These are found either upon the edges of the mantle or at the end of the siphons; and in some forms, such as *Spondylus* and *Pecten*, they are highly developed. The sexes are generally distinct, but occasionally united. The young are produced from eggs, which are either cast free in the water, or are hatched between the branchial lamellæ of the parent. The shell, as already stated, is composed of two pieces, right and left valves, which are protective of the soft parts, and correspond each to a lobe of the mantle. They are generally of equal size and shape, but in certain groups they differ considerably in these respects. They are nearly always joined dorsally by an elastic ligament, or *resilium*, and often interlocked at the same place by projections on the edges of the valves, termed hinge-teeth. In the majority of species the valves shut closely together all round the edges, but in many they gape at one or both ends, or at the ventral side. In certain species of *Pinna* the two valves are actually

united along the dorsal margin, but they are never connected on the ventral side. Bivalves clothe their shells with a more or less distinct periostracum, which is sometimes thin, smooth, and shining, and often of a yellowish or olivaceous tint, or it may be thick, pilose, velvety, or rugged. It has been already noticed that the valves are nearly always connected dorsally by a ligament. This is not, however, the means by which they are held together, or closed with such force; this closure being effected by one or two muscles (adductors), firmly attached to the inner surface of the valves, and endowed with such power of contraction, that it is an impossibility to force them apart without injury. The places of attachment of these muscles (*m*, *m′*) are generally visible, as well as other minor scars caused by the pedal retractor muscles. The point of attachment of the edge of the mantle, known as the pallial impression, is often quite distinct; it is parallel with the lower margin of the valves, and, in some groups, is more or less deeply sinuated (*n*) below the posterior adductor impression. All pelecypods are aquatic, the majority being marine. They are less numerous than gastropods in species, but in individuals are at present, as in past ages, relatively far more so. They are found at all depths, from low-water mark; many having been dredged in more than two thousand fathoms. Bivalves, however, are most abundant in shallow water. They live buried in the sand or mud, or attached to rocks and other substances, either by the shells themselves, or by means of a *byssus*, consisting of horny fibres secreted by a gland near the extremity of the foot. Others bore into rocks, wood, and other substances, and a few take up their abode in the tests of certain Tunicata, and in sponges, in the grooves of sea-urchins; and one species (*Entovalva*) lives parasitically inside a sea-cucumber. Dr. Pelseneer divides the class into five orders, based mainly upon the structure and morphology of the gills, but at the same time upon the general conformation of the animal. To explain in detail the differentiating anatomical characteristics of these orders would be beyond the scope of the present work, and consequently only salient features can be mentioned.



LEFT VALVE OF *Meretrix*.

a, Anterior; *b*, Posterior end; *c*, Umbo; *d*, Ventral margin; *m′*, Anterior adductor scar; *m′*, Posterior; *n*, Pallial sinus.

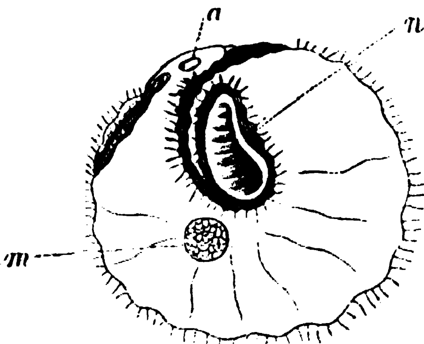
Order PROTOBRANCHIATA.

In these bivalves the gills have simple unreflexed filaments, disposed in two rows in opposite directions; the foot being expanded, with crenulated margins, and with scarcely any byssal gland. The families *Nuculidæ* and *Solenomyidæ* constitute this order. The molluscs belonging to the former are all marine; and have the mantle free all round, or forming two small posterior siphons. The gills are small, but the labial palpi very large. In the typical *Nucula* the shell is small, more or less triangular, generally covered with a greenish olive periostracum

without a pallial sinus, and pearly within. The hinge is composed of numerous pointed interlocking teeth on each side of the cartilage-pit beneath the umbones. Unlike *Nucula*, the genus *Nuculina* is provided with two small adjacent siphons. The shell is usually somewhat produced or beaked posteriorly, has a slight pallial sinus, and is not pearly within. The hinge-teeth and the resilium are as in *Nucula*. *Yoldia* is like *Nuculina* in shape, but has longer siphons, and the periostracum more glossy. The shells of *Malletia* are like those of *Yoldia*, but the ligament is external. *Nucula* and *Nuculina* have a world-wide distribution, and are numerously represented in species. *Yoldia* and *Malletia*, on the contrary, have comparatively a few representatives in Arctic, Northern, and Antarctic regions. The fossil forms belonging to this family are far more numerous than the recent, and include several generic groups which no longer exist. In the second family, *Solenomyidæ*, the animal is remarkable for its proboscis-like foot, expanded at the end into a flattened disc with a dentate edge. The mantle is united ventrally, but open in front for the passage of the foot, and posteriorly for the siphons. The shell is elongate, compressedly subcylindrical, without hinge-teeth, and clothed with a thick dark chestnut-coloured horny periostracum, which, when dry, is very brittle. Only about six species of one genus, *Solenomya*, are known, but these are widely distributed, being found in the Mediterranean, on the east coast of North America, in Patagonia, the Indian Ocean, Australia, and New Zealand.

Order FILIBRANCHIATA.

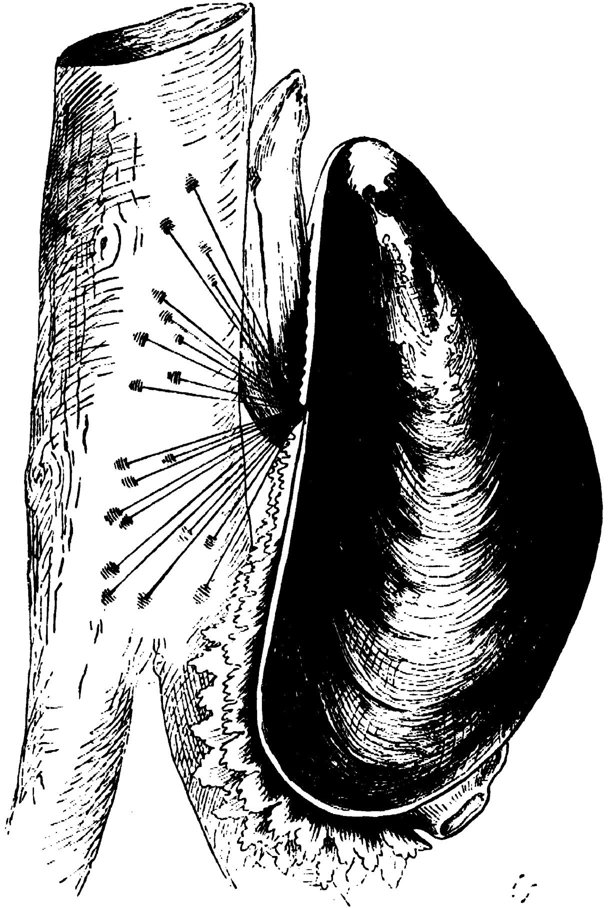
In this group the gills are smooth and their parallel filaments are directed ventrally, reflexed, and provided only with ciliated interfilamentary junctions; the foot being usually furnished with a byssal gland. In the family *Anomiidæ* the shells of the typical genus *Anomia* are generally very irregular in their growth, inequivalve, and somewhat pearly within; the more convex valve being remarkable for the large number of muscular impressions, and the flat valve for a perforation near the hinge. This aperture is for the passage of a calcified byssus (*n*), by means of which the mollusc attaches itself to rocks and stones. The animal has a small foot; the mantle is free all round, and there is but a single central adductor muscle (*m*). About forty species are known, two of which occur in Britain. *Placuna* is another genus of this family, in which the shells are very flat, without any byssal opening; the valves being thin, somewhat nacreous, with two long divergent hinge-teeth to which the ligament is attached. About half a dozen species from the Indo-Pacific Ocean are known. *P. sella* has a somewhat wavy or cockled appearance, and is known as the saddle-oyster, on account of its saddle-like form. The arks (*Arcidæ*) are nearly all strong heavy shells, generally equivalve, but in



RIGHT SIDE OF *Anomia*, WITH SHELL REMOVED.

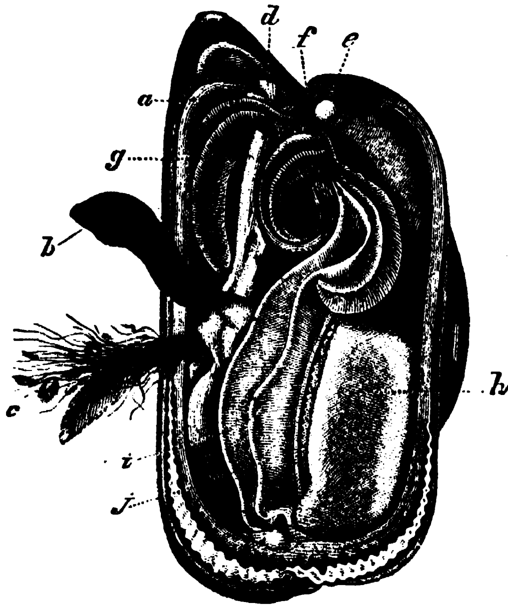
a, Opening for hinge; *m*, Adductor muscle; *n*, Calcified byssus.

some instances more or less inequivalve; and always remarkable for their straight hinge-line, furnished with very numerous teeth. The form is variable; but the valves are generally radiately ribbed, and more or less covered with a periostracum, which may be smooth and thin, or thick, and very rugged. They may either meet all round when closed, or may gape ventrally for the passage of a byssus. There are two adductors far apart, and the pallial line is simple. The species—both recent and fossil—are very numerous; and at the present time occur in all seas, some having a very wide distribution. For instance, the little *Arca lactea*, which is found on the British coast, also occurs in the Philippine Islands, the Red Sea, South Africa, Ascension Island, and the Mediterranean; and another species (*A. corpulenta*) has been dredged off North Australia, south of Amboyna, in Mid-Pacific, and off the coast of Chili, in depths ranging from two hundred to two thousand four hundred and twenty-five fathoms. In the allied *Pectunculus* the shell is rounded, strong, equivalve, with the hinge-teeth in a curved line; the outer surface being sometimes covered with a velvety or pilose periostracum. *Limopsis* somewhat resembles *Pectunculus* in form, but the shells are more compressed and clothed with a fibrous periostracum, and the animal spins a byssus. Several of the species have been dredged at enormous depths in the Atlantic. The genus *Trigonia*, represented by about half a dozen species occurring on the shores of Australia, is all that now remains of the large family *Trigoniidæ*, of which several other genera, with a very large number of species, occur fossil in the Secondary and Tertiary rocks. The valves of *Trigonia* are beautifully pearly within, equal, radiately ribbed, with an external ligament, and a few strong striated divergent hinge-teeth. The umbones are inclined posteriorly—a very unusual feature in bivalves. The foot of the animal is large and powerful, used in crawling and leaping, and without a byssus. In some of the Jurassic rocks of Weymouth trigonias form a bed several feet in thickness. Mussels (family *Mytilidæ*) are such well-known shells that a description is unnecessary. They are found all over

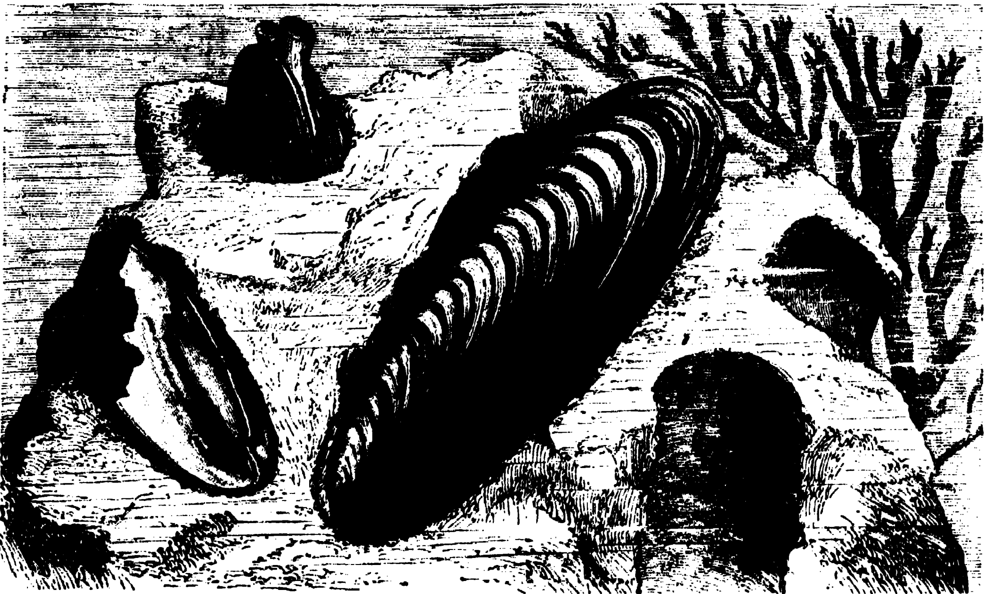


COMMON MUSSEL (*Mytilus edulis*), CLOSED AND ATTACHED BY THE BYSSUS (nat. size).

the world; one very large species from the shores of California sometimes reaching fully 9 inches in length. They anchor themselves by a byssus, but also have the power of moving from place to place, by casting off the byssus, extending the foot in the direction they determine to proceed, and attaching a byssal thread, which supports the animal while the foot is again extended and another thread spun. This process is repeated again and again, and thus progress is made. The structure of the animal may be understood by observing the accompanying illustration, where *a* represents the edge of the mantle; *b*, the foot; *c*, the byssus; *d.e*, the foot-muscles; *f*, the mouth; *g*, the labial palpi; *h*, mantle-lobe; and *i.j*, the inner and outer gill-plates. To the same family belong the date-shells (*Lithodomus*), which, as shown in the accompanying illustration, are stone-borers. The shells are date-like, thin, and covered with a yellowish or brown periostracum. The boring is chiefly effected by the foot. The columns of the temple of Serapis at Puteoli are perforated by a species of these molluscs, at a point far above the present sea-level, thus showing that these ruins must at some time have been submerged, and that the coast has changed its level within historic times at several epochs.

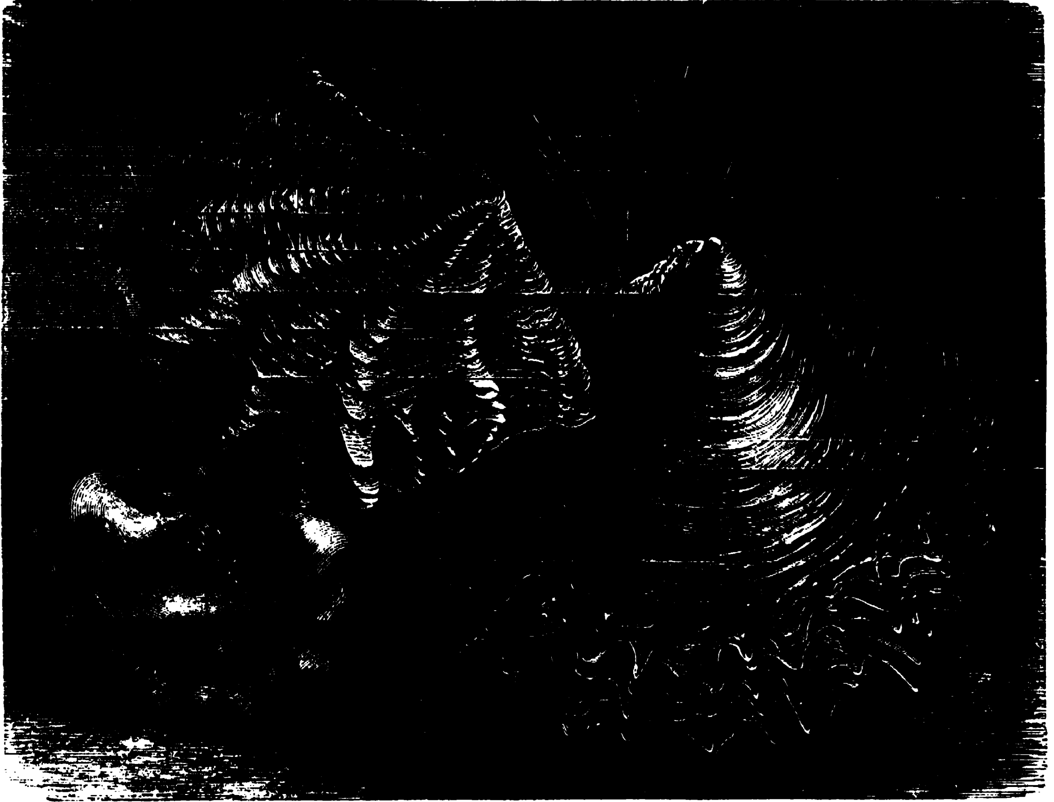


COMMON MUSSEL, OPENED TO SHOW THE VARIOUS ORGANS (nat. size).


DATE-SHELLS IN THE ROCK (nat. size).

Order PSEUDOLAMELLIBRANCHIATA.

The gills in this order are folded, and their filaments furnished with conjunctive or vascular interfoliary junctions; the mantle being free all round, and the foot small or absent. *Aviculidæ, Prasinidæ, Ostreidæ, Pectinidæ. Limidæ, Spondylidæ,* and *Dimyidæ* are the families constituting this order. The first family (*Aviculidæ*) is of importance as including the pearl-oysters. The shells are mostly compressed, but vary much in outline. In the typical genus *Avicula* the shell is oblique with a straight hinge-line, more or less produced into wings, which

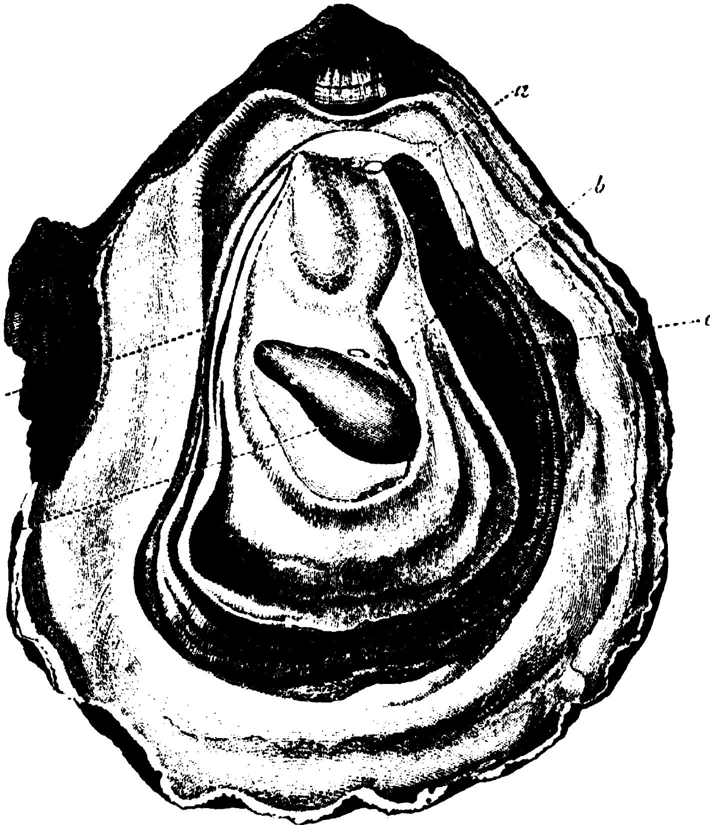


PEARL-OYSTERS (½ nat. size).

are sometimes long and slender. In the pearl-oysters, *Meleagrina,* there are, however, no wings, and in the case of *M. margaritifera* the shells become very thick and heavy. This species is one of the principal pearl-producers, and is largely collected by divers off the north coasts of Australia and other places, not only for the pearls which they may contain, but also for the shells themselves, which are valuable as mother-of-pearl. Until recently, the fishery was carried on by native divers, but now the diving-dress is largely employed. The Ceylon pearl-oyster, *M. fucata,* is much smaller than the Australian species. This fishery has been carried on for over two thousand years, and the accumulation of shells is so enormous as to extend for miles several feet deep. The shells are thin and of little use as mother-of-pearl, consequently they are thrown away, after being

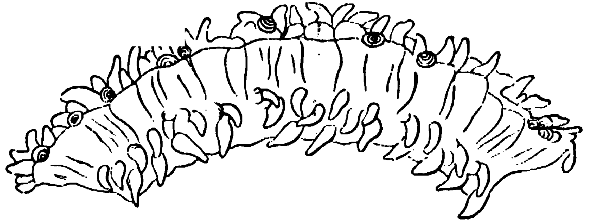
examined for pearls. Pearl-fishing is also carried on in the Persian Gulf, the South Sea Islands, Panama, West Indies, and a few other localities. The spherical pearls, like the shell itself, are produced by the mantle, and probably other parts of the animal also. They consist of layers of pearl, deposited round some foreign substance which has intruded itself within the shell. This may be a grain of sand, but is said to be usually an egg of the mollusc itself, which has not properly developed. The hammer-oyster (*Malleus*), *Vulsella*, *Crenatula*, and *Melina* are other interesting existing forms of *Aviculidæ*, and many extinct genera have been referred to this family.

The shells of the oysters (*Ostreidæ*) are so familiar that no description is necessary. The animal has no foot, and the mantle-lobes are free nearly all round, the borders being fringed with short papillæ. The shells, excepting in the very early stages, are closed by a single adductor. The sexes are separate in the American oyster (*Ostrea virginiana*), but united in the British *O. edulis*. In a gastronomic point of view the oyster stands far above all other molluscs, and its artificial cultivation was practised by the ancient Romans, and at the present time forms a most important industry in many parts of the globe. The oyster is very prolific, a single individual of the common species having been estimated to contain over a million embryos, whilst the American form is said to discharge ten times as many. *O. edulis* is not full-grown until about five to seven years old. Oysters are incapable of motion, and attach themselves to other shells, rocks, and other substances by the convex or deeper valve. During May, June, and July, the eggs are discharged into the gills, where they remain until hatched; and it is during this period that oysters are out of season. Oysters are cosmopolitan; wherever there is a rocky coast, excepting in Arctic climates, they are sure to

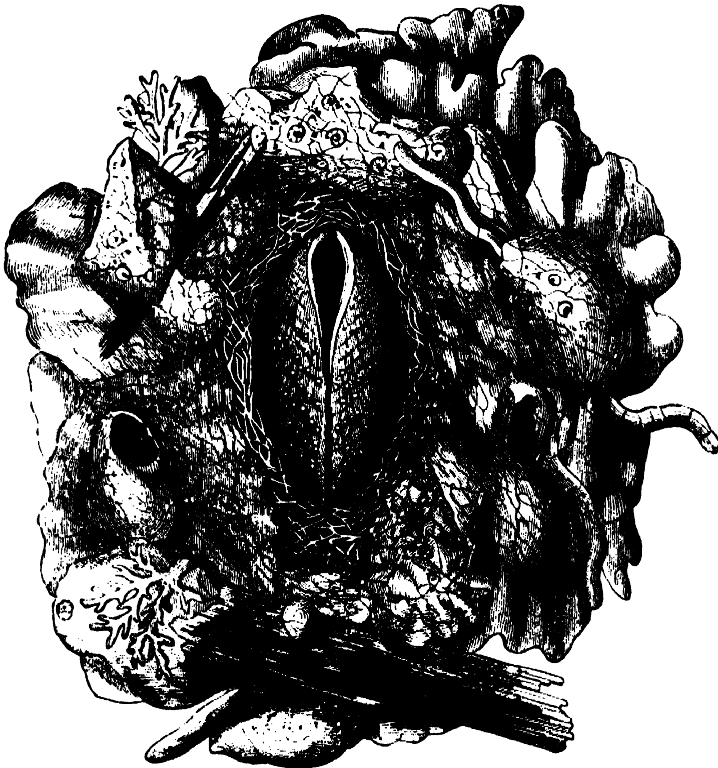


ONE VALVE AND SOFT-PARTS OF COMMON OYSTER.
a, Position of mouth; *b*, Mantle; *c*, Adductor; *d*, Junction of mantle-lobes; *e*, Gills. (Nat. size.)

be found. They are irregular in their growth, and consequently the determination of the species is a matter of difficulty. The pectens or scallop-shells (*Pectinidæ*) are remarkable for the variety and beauty of their coloration and sculpture. In most species the shells are nearly equivalve; but in a few, of which the common edible scollop is an example, the right valve is convex, and the left flat. One species (*Pecten jacobæus*) of the Mediterranean was worn as a badge by pilgrims who had been to the Holy Land. Most of the pectens are ornamented with radiating ribs, but a few are smooth. Some swim freely by flapping their valves, others live permanently attached by a byssus. The animal has the mantle free, and frequently bears a row of brightly coloured eyes on the margin. The foot is small, the gills are extremely delicate, and the single adductor muscle in the adult is excentric. They are generally hermaphrodite, but sometimes the sexes are separate. More than a hundred species from all parts of the world and all depths have been described. Ten occur on the British coasts, and fossil species are numerous in all formations, from the Carboniferous. The file-shells (*Limidæ*) somewhat resemble the scallops, but are nearly always white, and the edges of the mantle, which have no eyes, are furnished with long tentacular filaments. Some swim freely by flapping their valves, others attach themselves by a byssus, or, as in the accompanying figure, construct a nest of broken shells, stones, and other substances held together by a network of byssal threads. The two largest species occur off the coasts of Norway and Japan. The recent species of the chief genus (*Lima*) are not numerous, and some occur at



MARGIN OF MANTLE OF PECTEN, SHOWING TENTACLES AND EYES (somewhat magnified).



FILE-SHELL (*Lima*) IN ITS NEST (nat. size).

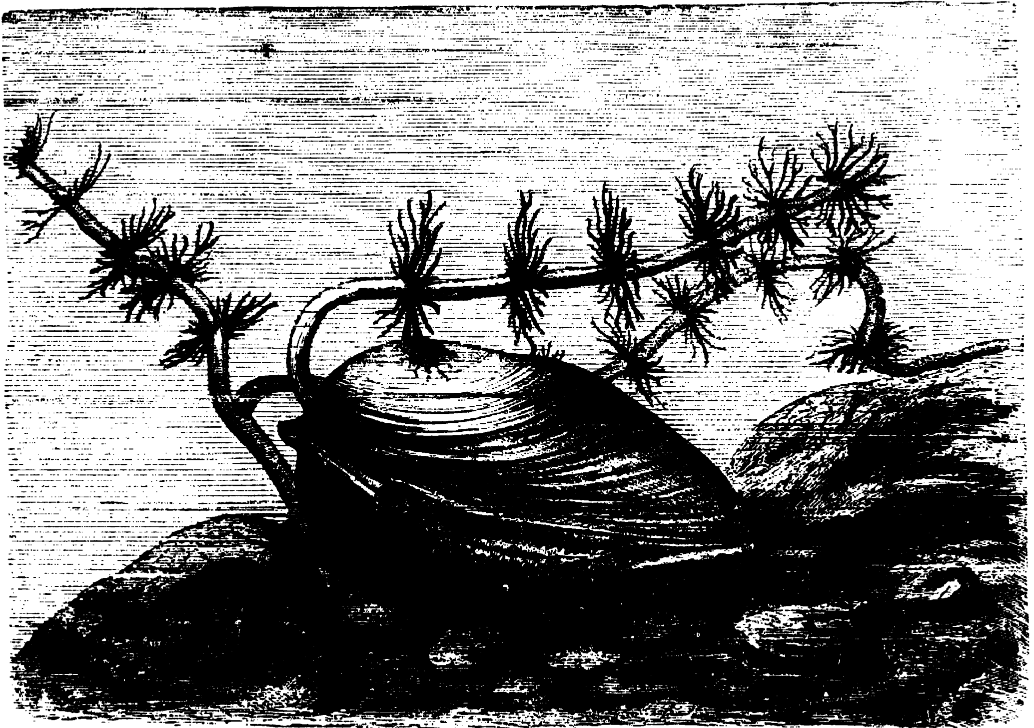
great depths. The fossil forms, on the contrary, are more abundant, from the Carboniferous age, and some of the species from the Lias (*Plagiostoma*) are of very large size. The members of the allied family *Spondylidæ* are known popularly as thorny-oysters, on account of the spiny character of their surface-ornamentation. In general shape they are rather like the pectens, and similarly brilliantly coloured; but they have much more solid shells, and the hinge consists of powerful interlocking teeth, while the animal has no byssus, a more rudimentary foot, and lives, with a few exceptions, attached by one of the valves to rocks and stones. The ligament of *Spondylus* is internal. The single adductor muscle is a little excentric, and the mantle-margin has a row of eyes.

Order EULAMELLIBRANCHIATA.

In this order the gills have vascular, interfilamentary, and interfoliary junctions; and the mantle is always united at one or more points, and there are generally two adductor muscles. The order is the largest of all, and comprises nearly sixty different families, of which only the most important or remarkable can be mentioned. In the first (Submytilacea) of several suborders into which the order is divided, mention may be made of a curious little species of the family *Carditidæ*, namely, *Thecalia concamerata*, which is a native of South Africa, and remarkable for a cup-like process formed by the female within the ventral margin of the valves, serving as a nursing-pouch for the young. *Milneria minima*, a Californian species, forms a similiar marsupium. In the family *Cyprinidæ*, *Isocardia cor* is one of the finest of the British bivalves; and is a large strong globose shell, with the umbones prominently curved anteriorly. The ligament is external, and the hinge-teeth are strong and of peculiar form. The animal has short siphons, large gills, and a small foot for burrowing in the sand. In the *Lucinidæ* the shells are mostly white, round, globose, or compressed, and peculiar on account of the great length of the anterior muscular scar, which falls within the uninterrupted pallial line. Sometimes the animals have only a single branchial lamella, and the foot is generally slender and without byssus. The families *Leptonidæ*, *Galeommidæ*, and *Chlamydoconchidæ* also belong to this order. *Lepton* often lives commensally with Crustacea, *Galeomma* has the mantle reflected over a considerable part of the valves, and in *Chlamydoconcha* the shell is wholly covered by the mantle, a unique feature among the bivalves. The family *Ætheriidæ* includes a few remarkable bivalves known as fresh-water oysters. They occur in the Nile and some other rivers of North Africa, and some parts of South America. When young, *Ætheria* is a freely creeping mollusc, but when adult becomes attached to stones and other substances like the oyster. The shells are irregular in their growth, and are of an olive-green colour. The somewhat pearly interior of the valves is marked with two adductor scars, and the pallial line is entire. They may be regarded as irregular forms of *Unionidæ* without a foot, modified for a sedentary life.

The numerous kinds of fresh-water mussels (*Unionidæ* and *Mutelidæ*) occur in the lakes and rivers of all continents, and the large islands of the Malay Archipelago and New Zealand; although in most of the smaller islands they

are unknown. North America, and especially the drainage-area of the Mississippi and its tributaries, is the great home of the *Unionidæ.* The species may be counted by hundreds, some being the most remarkable and beautiful that exist in any part of the globe. The shells are usually equivalve, and joined by an external ligament, but exhibit great variation in shape. The hinge is sometimes destitute of teeth (*Anodonta, Mycetopus*); or powerfully formed with strong complex interlocking teeth, as in many of the North American forms; or it may consist of very numerous teeth on a straight hinge-line (*Pliodon*), recalling the form of hinge obtaining in the *Arcidæ.* The exterior is covered with a thick, often glossy periostracum, varying in colour, the prevailing tints being



LARGE RIVER-MUSSEL, *Anodonta cygnea* (nat. size).

greenish olive, brownish yellow, brown, and black. Many are beautifully rayed with green. The solidity of many of the species—especially the North American forms—is remarkable, although others are thin and fragile. Some are pearly within, and others white, pinkish purple, salmon-colour, yellow, or iridescent. The shells are marked with two adductor scars, and the pedal scars are also often clearly visible, while the pallial line is uninterrupted by a posterior sinus. The animal of *Unio* has the lobes of the mantle free, excepting posteriorly, where they are connected, forming two orifices, the lower or branchial for the passage of the water to the gills, and the upper for excretal purposes. The former is fringed with several rows of papillæ. The foot is large, thick, tongue-shaped, and used as a creeping and burrowing organ. The sexes are united in the European species, but distinct in the American. A remarkable feature in con-

nection with the *Unionidæ* is the parasitic life of the early stages. The eggs, after being hatched between the gills of the parent, and having undergone the first stages of development, subsequently develop into minute bivalves, each valve having a hook-like process on the front edge, and are expelled from the brood pouches. They at once attach themselves to some extraneous object, by means of a byssal thread, and at this stage are known as *Glochidia*. They attach themselves, as soon as possible, to the gills and other parts of fishes, by means of the valve-hooks, and there complete their metamorphosis, finally quitting their host, sinking to the bottom, and assuming the parent form. Four species are found



PEARL-MUSSELS (*Unio margaritifer*), SHOWING PEARL WITHIN THE SHELL, AND DETACHED PEARLS (1-8).

in Britain, one of which (*Unio margaritifer*) is famous for the pearls it produces. Some of the rivers of Scotland, and the Conway in North Wales, have always had a great reputation for their pearl-fisheries. Although not equal in lustre to the Oriental jewel many of these river pearls are beautiful. Unlike *Unio*, the *Dreissensiidæ*, as represented by *Dreissensia*, have the mantle-margins united ventrally, with an anterior opening for the slender foot and byssus, and prolonged posteriorly into two siphons. The shell is shaped like the common marine mussel. The European *D. polymorpha* was first noticed in England about seventy years ago, and is supposed to have been introduced attached to Russian timber.

Suborder **Tellinacea.**

This group includes the families *Tellinidæ*, *Scrobiculariidæ*, *Donacidæ*, *Mactridæ*, *Mesodesmatidæ*, and *Cardiliidæ*, the first of which is the most extensive, and contains the most beautiful forms. Here the animal is remarkable for the great length of the slender separated siphons, the fringed mantle-margins,

and large labial palpi and foot. The shells are nearly always compressed, subequivalve, joined by an external ligament, and furnished with hinge-teeth. The scars of the adductors are far apart, and the pallial impression is generally very deeply sinuated. None of the bivalves are more beautifully coloured than the tellens, the prevailing tints being purple-red, crimson, and various shades of yellow. The surface-sculpture of the valves is often beautiful and delicate. Tellens live in sand or mud at slight depths in every sea, and the species may be counted in hundreds. Nine species of *Tellina* are British. The *Scrobiculariidæ* form a smaller and less showy family than the preceding, the shells being united by an internal ligament, and sometimes by an external one also. The soft-parts are like those of the *Tellinidæ*. Some species of the genus *Abra* have been dredged at enormous depths, both in the Atlantic and Pacific, but the majority of the family have been obtained in comparatively shallow water. The British *Scrobicularia piperata* buries itself in the mud of estuaries, and can extend its siphons five or six times the length of its shell. Although in some respects the wedge-shells (*Donacidæ*) agree with the *Tellinidæ*, they differ as regards the gills. In *Donax* the shells are of a triangular or wedge-shape, and have the inner margin of the valves crenulated. They are united by an external ligament, and furnished with cardinal and sometimes lateral teeth. The wedge-shells live buried in the sand in shallow water in warm regions all over the world, and three species occur on the British coasts. The genus *Iphigenia*, which has no lateral teeth, inhabits estuaries on the coast of Africa, Brazil, the West Indies, and Central America. In the mactras (*Mactridæ*) the shells are often more or less triangular, and have an internal ligament, the siphons being united the entire length, and fringed at the ends. About one hundred and fifty species of *Mactra* are known. They occur on sandy shores in most parts of the world at shallow depths, six being British. This family comprises a large number of genera and subgenera, mainly distinguished by modifications of the hinges; *Mulinia*, *Spisula*, *Standella*, *Rangia*, *Ræta*, and *Eastonia* being the more important. The remaining familes, *Mesodesmatidæ* and *Cardiliidæ*, are not of special importance, and may be passed without further reference.

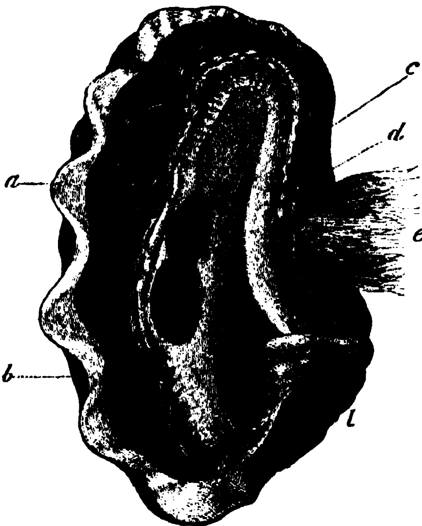
Suborder **Veneracea.**

In the *Veneridæ*, which form the first family of this group, the animal has rather short, more or less united siphons, with fringed openings. The mantle is open in front for the passage of a tongue-like foot, which is sometimes furnished with a byssus. The shells are solid, equivalve, and often beautifully coloured and sculptured, with the hinge-teeth large and divergent, and the ligament external. In the typical genus *Venus* the shells are more or less circular, globose, and often have the surface cancellated, and the inner edge of the valves crenulated. There are several British forms of *Veneridæ*, but none are eaten to any great extent. On the contrary, the large *Venus mercanaria*—the clam of the Atlantic States of North America—is sold in large quantities in the fish-markets of New York and Philadelphia. In *Dosinia* the shells are more compressed, circular, and marked within with a deep, narrow, pallial

sinus. In *Circe*, on the contrary, the mantle-impression is unsinuated. The shells of *Tapes* are longer than the typical forms; the foot is long, grooved, and frequently furnished with a byssus, the siphons being separate at the ends and beautifully fringed. They are most abundant in the warm seas of the Eastern Hemisphere, but four species range as far north as England. The large species of the allied genus *Cyrena* are found in brackish water at the mouths of rivers, and in mangrove-swamps; while the smaller forms known as *Corbicula, Sphærium,* and *Pisidium* occur in fresh water in most parts of the world. The shells of the last two groups are very similar, but the animals are readily distinguished by the number of the siphons. In *Sphærium* there are two which are united at the base, but separated at the extremities, whereas in *Pisidium* only a single anal siphon is present. In this genus the water is conveyed to the gills through the pedal opening of the mantle. There are four British species of *Sphærium*, and five of *Pisidium*, all of which possess the faculty of floating in an inverted position at the surface of the water, or they suspend themselves from the surface by a fine byssal thread. One species (*P. pusillum*) does not require a constant, or even a frequent supply of water, often living at the roots of bog-moss and grass, and it has also been found between the bark and wood of fallen trees in moist places.

Suborder **Cardiacea.**

The *Cardiidæ*, *Tridacnidæ*, and *Chamidæ* are the principal families belonging to this suborder of which there are living representatives, but a few extinct families, such as the *Hippuritidæ*, are also considered to belong here. The cockles (*Cardiidæ*) abound in shallow water in most parts of the world, where there are sheltered sandy bays. Some of the exotic forms are beautifully sculptured, and their colours also are often very bright and varied. The animals have short fringed siphons, and the long foot is bent and used for leaping. Probably many are eatable, like the common cockle. In addition to this kind, nine species are found on the British coast. The typical species of *Cardium* have the convex valves ribbed, the ribs interlocking at the margins. In *Lævicardium* the shells are smooth, in the beautiful *Cardissa* they are flattened, heart-shaped, and keeled at the sides. The true clams (*Tridacnidæ*) differ from other bivalves with united mantle-margins in having only a single adductor muscle, like the oyster, the anterior being obsolete. The mantle has three distant openings, pedal (*d*), branchial (*a*), and anal (*b*). The foot is small, finger-like, and capable of producing a stout byssus (*e*). The shells are equivalve, ponderous, with a few stout ribs radiating from the umbones, and



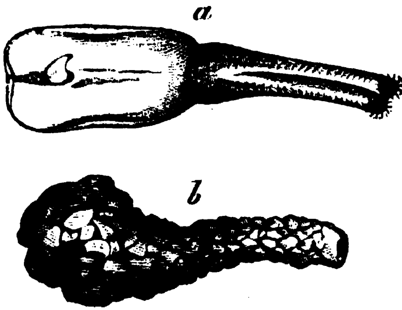
VALVE AND SOFT-PARTS OF *Tridacna*.

terminating on the edge of the valves in pointed projections. The genus *Tridacna* contains the largest of all bivalves, *T. gigas* sometimes measuring more than a yard in length, and weighing as much as 500 lbs. The animals are gorgeously coloured, and a mass of them nearly a mile in extent has been compared to a bed of tulips. The six or seven species are found in hot latitudes, such as the Red Sea, and Indian and Pacific Oceans. The adductor muscle is said to be good eating. *Hippopus* differs from *Tridacna* in having no gape in the anterior end of the shell for the passage of a byssus. *H. maculatus* is one of the most common shells used as ornaments. The *Chamidæ* are remarkable for their strong irregular oyster-like shells, which are often brilliantly coloured, and covered with spines or ridges like the thorny-oysters. The shells exhibit two well-marked muscular scars, strong hinge-teeth, and an external ligament. These bivalves inhabit tropical or subtropical seas, and are usually attached by one of the valves to rocks. The animal has the margins of the mantle united, excepting at the siphonal openings and the pedal orifice. To a mollusc leading a stationary life, and not given to spinning a byssus, a foot would appear to be useless; nevertheless *Chama* possesses a reduced form of this member, but what purpose it serves it is difficult to conjecture. Some of the fossil members of this family, *Diceras* and *Requienia*, for example, have remarkable shells, quite unlike those of the existing forms.

Suborder **Myacea.**

In the family *Psammobiidæ* the typical genus *Psammobia* has the siphons very long, slender, and separated as in *Tellina*, the foot large and tongue-like, and the edges of the mantle fringed. The shells are long and narrow, compressed, slightly gaping at both ends, generally somewhat obliquely truncate posteriorly, often brilliantly coloured, and beautifully sculptured. Four species occur on the British coasts. The gapers (*Myidæ*) take their title from their widely gaping shells, which are covered with a wrinkled periostracum extending also over the siphons; these being united their whole length, and fringed at the ends. *Mya arenaria*, a common British species, also abounds on the sandy shores and mud-flats of the Eastern States of North America, where it is eaten in quantities. The clams, as they are commonly called, live in deep burrows in the sand or mud, the shells often being a foot below the surface. A recent writer observes that when the flats are covered with water, the clams extend their long siphons up through the burrow to the surface of the sand, and through one of these tubes the water and its myriads of animalcules are drawn down into the shell, furnishing the gills with oxygen, and the mouth with food, and then the water, charged with carbonic acid and fæcal refuse, is forced out of the other siphon. Two species of *Mya* constitute the staple food of the walrus. The *Solenidæ*, or razor-shells, are also great sand-burrowers, and indeed bore with such rapidity, and to such a depth, that they often elude capture. They possess very elongate shells, and are remarkable for the great development of the foot. They not only burrow in sand, but also have the power of darting through the water like scallops. They are eaten by the poorer coast population. In the *Saxicavidæ* the species of the typical genus *Saxicava* are some of the few bivalves which have the power of boring into limestone and other soft rocks, although they

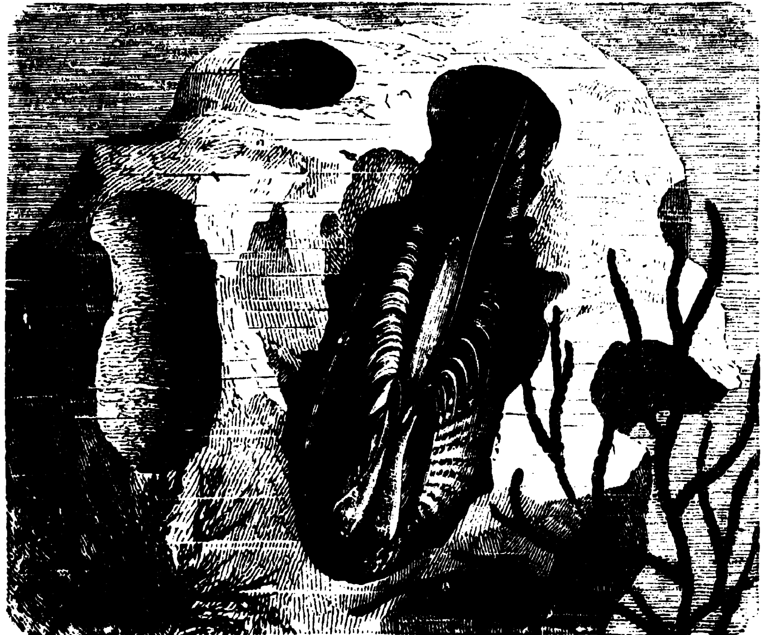
more often hide in crevices or at the roots of seaweed, mooring themselves by a byssus. The shells are very irregular, their form varying according to the hole or crevice they inhabit. In the *Gastrochænidæ*, forming the last family of this group, *Gastrochæna* comprises bivalves which live buried in the sand. These form a long, slender, club-shaped fragile tube, covered with adhering particles of sand, and divided off by a partition into two portions, the anterior containing the shell, the posterior or narrower end the siphons. The animal of the allied *Rocellaria* is similar, but forms no tube, and has the habit of boring into solid rock, shells, and other substances; *R. dubia* being found in limestone, and even granite, on the British coasts.



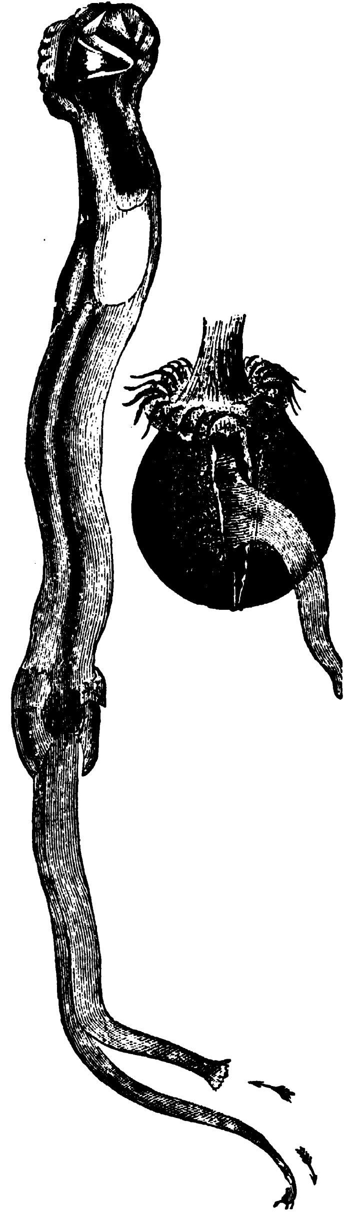
ANIMAL (*a*) AND CASE (*b*) OF *Rocellaria*.

Suborder Pholadacea.

The boring *Pholadidæ* and *Teredinidæ* are the only families contained in this suborder of the group, the former perforating clay, chalk, limestone, and even gneiss. Their shells are always white, thin, but hard and strong, and ornamented with prickly rasp-like sculpture. They gape all round the valves, meeting only at the hinge and the opposite margin. Accessory plates generally occupy the vacant spaces. The valves have no hinge-teeth, and are not connected by a well-defined ligament, like most bivalves. The animals have long united siphons, fringed at the apertures, and enclosed in a tough skin, which is often protected by cartilaginous cup-like processes. In the typical *Pholas* the foot is well developed, and probably forms the principal excavating instrument; the shell being used as a file to enlarge the crypt as the creature grows. *Xylophaga* and *Martesia* bore into floating wood. Species of this family are met with everywhere, and about half a dozen occur on the British coasts. In some parts of Europe *Pholas* is considered


Pholas IN ITS BURROW (nat. size).

a delicacy, and many species are highly phosporescent. In the second family the ship-worm (*Teredo*) is only too well-known on account of the amount of damage it does to submerged timber. It matters not whether it be oak, pine, teak, or mahogany which it attacks, soon the timber is riddled through and through, and rendered useless. In former times, before the invention of copper-sheathing, immense damage was inflicted upon shipping, and the piles of piers and harbours were constantly having to be renewed through the ravages of this pest. The Dutch have been great sufferers, and at one time such depredations had been made on the piles which support the dykes of Zealand and Friesland as to threaten them with total destruction. The animal is practically nothing more than an extremely prolonged *Pholas*. The siphons are of immense length, in some cases from two to three feet long, united except towards the ends. On the contrary, the body itself containing the principal viscera is small, and protected by a globular, bivalved shell, open both in front and behind. The gills are narrow, elongate, and prolonged into the branchial siphon. The siphons secrete a shelly lining to the burrow, and at the point where they separate there are a pair of calcareous plates, or pallets as they are termed, probably used as a means of defence, in closing the tube after the siphons have been retracted. Ship-worms generally bore with the grain, only turning aside to avoid a knot or any other obstruction; and although their burrows are almost touching, they seldom appear to run into one another. The animal does not feed upon the wood it excavates, but ejects it in small particles through the siphon. The foot is probably the burrowing organ, but the method of excavation is still imperfectly understood. *Hyperotus*, *Nausitoria*, *Xylotrya*, and *Cyphus* are other forms of *Teredinidæ*; the last named constructing a strong, shelly tube, sometimes a yard long, and two inches in diameter, in which the creature lives buried in the sand.

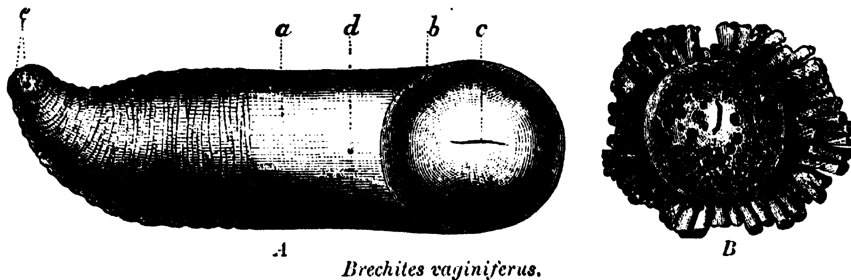


SHIP-WORM (*Teredo*) AND ITS LARVA.

Suborder **Anatinacea.**

This, the last suborder of the Eulamellibranchiata, contains thirteen families of which only a few are of general interest. Of the *Pandoridæ*, the typical *Pandora* is distinguished by its compressed, internally pearly shell, which is sometimes semi-lunate in form; the right valve being flat, and the left somewhat convex. *P. inæquivalvis* is a common British species. In *Myadora*, an allied genus, the left valve is flat, and the right convex. The species of the third genus, *Myochama*,

attach themselves to other shells by their right valve, the left being ornamented with radiating ridges. Among the other families, *Anatina*, *Thracia*, and *Pholadomya* are interesting genera, the last on account of its rarity in the living condition, and its numerous representatives in bygone ages. *Brechites*, or *Aspergillum*, is remarkable, as it is only in the earliest stages of existence that it presents the appearance of a normal bivalve. It subsequently forms an elongate tube, open at one end and closed at the other by a frilled disc full of holes, like the rose of a watering-pot; embryonic valves being embedded in the surface near the rose. The illustration shows the contracted animal extracted from the shell, (*e*) indicating the siphonal openings, (*c*) the mantle aperture, (*b*) the anterior side, (*a*) the mantle, (*d*) foot opening.



Brechites vaginiferus.
A, Animal contracted, withdrawn from shell; *B*, Anterior end of the shell.

Order SEPTIBRANCHIATA.

The members of this group are readily distinguished by the circumstance that the gills are transformed into a muscular septum, extending from the anterior adductor to the separation of the two siphons, and surrounding the foot, with which it is continuous. This septum presents symmetrical orifices. The siphons are sometimes short, or more or less produced. There are two adductors, and the mantle-edges are united at three points. There are two families, namely, the *Poromyidæ* and *Cuspidariidæ*. Of the former, *Poromya* has the siphons short, unequal, separate, and surrounded by a tentacular fringe; each half of the septum having several groups of lamellæ, separated by orifices; the foot being slender, long, and the palpi larger. The shells are often minutely granular and somewhat pearly within. The species are small, few in number, and mostly from very deep water. *Silenia* is a deep-water form, dredged in 1950 fathoms, about eleven hundred miles south-west of Australia, and also in the South Atlantic at the enormous depth of 2650 fathoms. The *Cuspidariidæ* is a more extensive family, and although the species are nearly all small, some are elegant in form, and prettily sculptured. The shells have been classified by characters derived from modifications of the hinge, and the surface ornamentation. The siphons are longer than in the *Poromyidæ* and united with tentacular fringes at the ends; the foot is moderately long and pointed, the labial palpi are rudimentary or wanting, and the branchial septum is pierced with isolated symmetrical orifices. The shells are mostly transversely ovate, and produced posteriorly into a more or less elongate rostrum. They are found in all seas, in depths ranging from a few fathoms to over three miles.

EDGAR A. SMITH.

CHAPTER XII.

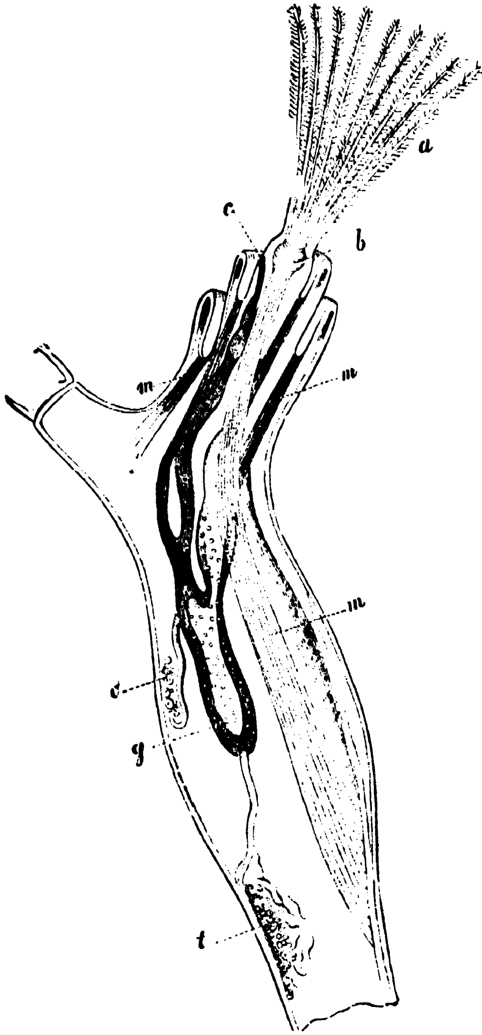
MOSS-ANIMALS AND LAMP-SHELLS,—Subkingdom **MOLLUSCOIDEA.**

THE exact positions in the animal kingdom of the Bryozoa or moss-animals, and the Brachiopoda or arm-footed animals, which are generally united under the name of Molluscoidea, is still far from settled. The Brachiopods were long placed with the Molluscs, and the Bryozoa with the Corals and Sponges; but fuller knowledge made it evident that the Bryozoa did not in any way belong to the latter. Next, they were classed with the Rotifers, or wheel animalcules, under the name of Ciliata, as a kind of appendage to the worms, while by others they were grouped with the Ascidians. They are here placed with the Brachiopoda, not because the two groups are really related, but simply because they are alike in having no established place in the classification of the animal kingdom. It is true that the Bryozoans and the Brachiopods are sometimes classed together because of the similarity of their development, and also for certain supposed anatomical resemblances between them; but these latter are far from convincing, and the similarity of their larval histories has been disputed.

MOSS-ANIMALS,—Class **Bryozoa.**

The moss-animals almost always live in colonies, the individuals of which are joined in a number of different ways to form stocks. The individual animals are small, and the stocks generally also small, never forming anything approaching the masses of substance yielded by those of the corals. The structure of the Bryozoan animal can be studied in the accompanying figure, which shows, greatly magnified, the external outline and the inner organs of a single individual belonging to the stock of a fresh-water form (*Paludicella*) from Belgium. The individual figured has been detached at its base from the one below it, and the one next above is broken off. The body is represented by a chamber or cell, in this case somewhat elongated. Its walls are stiff, except at the anterior end, where they are flexible enough to allow the crown of tentacles (*a*) to be protruded as in the figure, or to be withdrawn by means of muscles (*m*). One of these muscles is seen to be specially powerful, and runs through nearly the whole length of the cell. The mouth is at the anterior end of the body, surrounded by the circle of ciliated feelers or tentacles (*a*). The alimentary canal, which commences with a muscular pharynx (*b*) hangs down in the form of a loop into the body-cavity, the stomach (*g*) being its lowest portion. Its terminal portion runs again towards the anterior end, so as to open not far from the mouth (at *c*). The whole alimentary tube is but loosely fastened to the body-wall, its chief attachment being by means of a single short strand at the end of the stomach called the funiculus, and shown in the illustration. In all adults, two masses of cells are

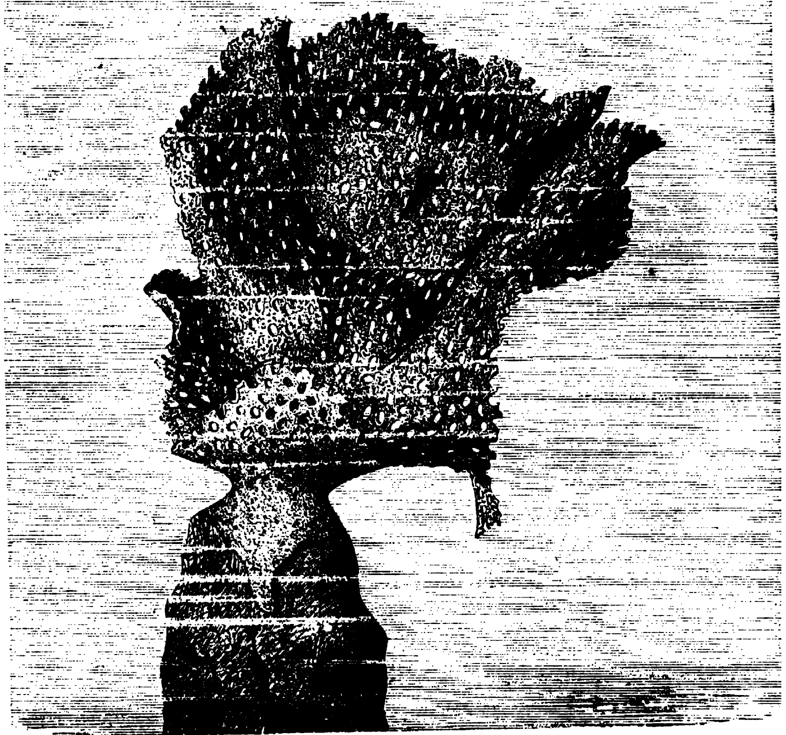
found attached to the wall of the chamber, the upper (*o*) yielding eggs, while within the lower (*t*) the male elements develop. Moss-animals are therefore hermaphrodite, the fertilisation of the eggs being effected by the two elements mingling freely together in the body-fluid. In all essential points, the above description would apply to any one of the seventeen hundred species, fossil and extant, which are known.



SECTION OF AN INDIVIDUAL OF *Paludicella* (highly magnified).

Among the larger colonies may be mentioned certain fresh-water genera, found attached to the roots and branches of water-plants, which may form considerable masses; but these stocks are dull in colour and very inconspicuous, the beauty of the minute individual animals themselves being invisible to the naked eye. Some fairly-sized forms occur also among the marine genera, which are often marked by the great variety and beauty of their stocks. Many of these are delicate branching or tree-like growths some inches in height; take, for instance, the sea-mats (*Flustra*), or again, the still larger and more beautiful lace-corals, Neptune's sleeves, such as are shown on p. 421, which, in spite of their name, are not true corals but bryozoans. The figured lace-coral (*Retepora*) is found in the nets used on the shores of the Atlantic Ocean and Mediterranean Sea. When fresh, the stocks—which resemble a fine, cup-shaped, or folded and frilled piece of lace—seem to be covered by a reddish organic mass, out of which arise the delicate tentacular crowns of the individual animals. These are, however, too small to be seen, except with a magnifying glass. When the soft-parts are removed, the stock is of dazzling whiteness, consisting chiefly of the chalky substance which binds the separate individuals together into a colony. Between the open meshes of the lace-work, multitudes of minute apertures are to be seen, which are the openings of the individual chambers or cells containing the bodies of the animals, and into which they can withdraw their tentacular crown as above explained. Another lace-coral from the Mediterranean is shown on p. 422. It rests upon a branched structure, a common calcareous alga which grows on a stone. The individuals of this genus (*Lepralia*) are arranged in rows, and are further distinguished from *Retepora* and other moss-animals by the fact that the animals occur only on one side of the stock. We mention these lace-corals because of their being com-

paratively conspicuous; but we might have chosen any other of the many beautiful but less conspicuous forms. On any sea-coast a harvest of them can be gathered in a few days. Certain species are almost always to be found on nearly every leafy seaweed, and where the bottom of the sea is favourable, stones and the shells of molluscs, both full and empty, are covered with stocks of Bryozoa, often only discoverable by means of careful examination with a magnifying glass. Owing to the hardening and frequent calcification of the greater part of the body-wall to form the cell into which the anterior part that always remains soft can be withdrawn, these animals are often found as fossils. The marvellous variety of forms presented by these delicate little stocks is in each case determined by the particular manner of budding. The first animal which, by budding, gives rise to the stock is produced from an egg, and begins to bud as soon as it has become attached. In each family or species the buds appear at special points, and assume definite positions with regard to the parent individual. The smallest variation in this respect causes the profoundest changes in the forms of the stocks produced. Their classification is determined principally by the structure of the mouth and of the tentacle crown, as may best be gathered from a few examples. We take first the subclass Ectoprocta.



LACE-CORAL, OR NEPTUNE'S SLEEVE, *Retepora cellulosa* (nat. size).

Order Phylactolæmata. Most of the fresh-water moss-animals belong to the order Phylactolæmata, so-called because the mouth is provided with a tongue-shaped lid. The crown of tentacles, which is also a gill, is horseshoe-shaped, and the whole surrounded at its base by an integument forming a kind of calyx or cup. The chambers or cells are either quite soft or else horny, and are thus not found in a fossil condition. Later on in this volume is described a colony of sea-anemones which, instead of being fixed, as are most stocks, are

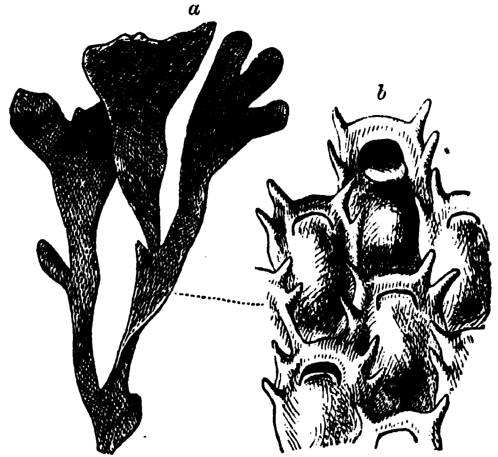
able to travel about; a colony of moss-animals capable of locomotion is figured on p. 425. These remarkable moving types (*Cristatella*) form flattened, elliptical colonies, which creep along on a kind of flat foot, following the direction of the light. The question may be raised as to how the many separate individuals manage to move in the same direction. Even if an external stimulus, such as light, should stimulate the individuals in the same way, this seems hardly sufficient to account for the movement of the colony, without some nervous system connecting the polyps and co-ordinating the movements of the colony. As a matter of fact, such a system does exist. While each separate animal is provided with a nerve-ganglion between the œsophagus and the posterior opening of the alimentary canal (*c* in the illustration on p. 420), and with the nerves necessary for its own individual organisation, the Bryozoan colony, as such, has a special nervous system which is connected with the individual systems, and runs from one to another through the apertures by means of which also the body-fluids circulate throughout the colony. This colonial nervous system no doubt regulates the movement of the stock.



LACE-CORAL, *Lepralia* (nat. size).

Order Gymnolæmata. In contrast to the Phylactolæmata are the Gymnolæmata, those Bryozoa in which there is no lid to the mouth, and in which the tentacles are arranged in a circle on a disc instead of in the shape of a horseshoe; the name given to such forms denoting the naked condition of the mouth. These naked-mouthed Bryozoans are far more numerous than those with lids to their mouths. *Paludicella*, which is fully described on pp. 419, 420, is one of the few fresh-water forms belonging to this order. Here the crown of tentacles cannot be completely protruded, and thus appears, even when most extended, to be surrounded by a double collar. A numerous group of this order are the marine Chilostomata, or lip-mouthed Bryozoa, of which the sea-mat (*Flustra foliacea*), common in the North Sea, is an example. The magnified cells shown in the illustration represent the harder portion of the animals, into which the soft anterior portions can be withdrawn. The openings through which the tentacles protrude lie crosswise, and each is provided with a lip-like elastic lid. Each individual can thus take refuge within its chamber and close the lid. Other genera which, unlike *Flustra*, have no lid, can close the aperture by means of muscles. The colonies of sea-mats

form branched leaf-like lobes very common at the seaside, and often mistaken for seaweed. Each side of the leaf consists of a layer of closely crowded individuals. The cells only partly calcify, so that when fresh they are elastic, and the whole stock remains very flexible. To this suborder belong also *Retepora* and *Lepralia*, above mentioned.

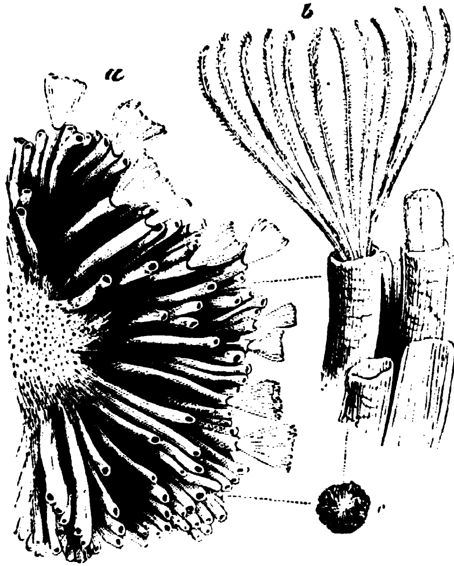


SEA-MAT (*Flustra foliacea*).
a, Stock (nat. size); *b*, Five cells (magnified).

An important rise in the scale of organisation is found in the Gymnolæmata, especially in the lip-mouthed forms, where a marked division of labour takes place; that is to say, the individuals which constitute the stock vary in structure and fulfil different physiological functions. There are structures known as *zoœcia*, *stolons*, *avicularia*, *vibracula*, and *ovicells*, some—perhaps all—of which are modified individuals. The *zoœcia* are the normal individuals of the colony, fully developed for most of the functions of life; respiration, taking in food, and digestion, and no doubt also for receiving sensory impressions. The *stolons* have a much humbler function, but are indispensable for the well-being of the colony. They are rootlike outgrowths of the stock, consisting of very simple individuals which serve for attaching the whole colony to foreign objects, such as stones, shells, etc. The most remarkable are the structures known as *avicularia*, so called because they resemble the head of a bird. The individual is turned into a pair of forceps, of which the large upper blade (very like the skull and upper jaw of a bird) and the smaller lower blade (like the lower jaw) constantly open and shut by means of a complicated arrangement of muscles. These *avicularia* are movably attached by a short neck, and are found near the entrance to a *zoœcium*. They turn from side to side, snapping in all directions, and, no doubt, every now and then catch some of the small worms, crabs, or larvæ which rest on the colony. The victims are held till they decay, and, as they break down, fragments are drawn into the mouth by the water currents caused by the cilia on the tentacles. These dead creatures act as baits, and attract other victims within the influence of the same stream. These also are drawn into the mouth. On account of these peculiar structures, the Chilostomata have been called the bird's-head corallines. Equally interesting again are the *vibracula*, long thread-like structures, attached by short stalks, which keep up a constant whip-like motion. Their function is not clear; but perhaps they may be specialised tactile organs, or may help to drive the minute prey within reach of the nutritive individuals. Lastly, we have the *ovicells*, or egg-receptacles, which are found at the lower ends of the *zoœcia* in the form of bells, helmets, or vesicles. It is uncertain whether these are independent modified individuals or merely appendages of the *zoœcia*, the latter view being the more probable.

Round-Mouthed Group. Another suborder of the Gymnolæmata consists of the Cyclostomata or round-mouthed Bryozoans. In the tube-like forms (*Tubulipora*),

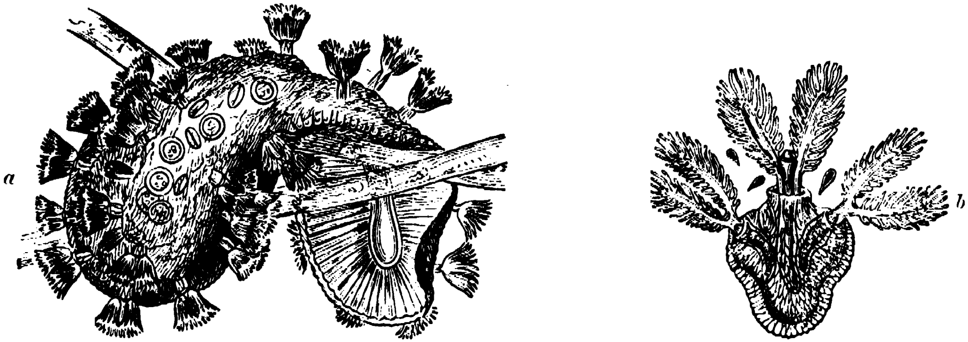
which may be taken as typical of this suborder, the relation between the infolding portion of each individual and the rigid cell differs from that in the Chilostomata; and the aperture of the cell is terminal and wide, passing into the soft anterior end without narrowing. *Tubulipora* is one of the numerous round-mouthed forms, the stocks of which form cup-shaped incrustations, the individuals radiating outwards as seen in the magnified figure (*a*). In Fig. *b*, several cells are still more highly magnified. Fig. *c* shows the natural size of the colony.



Tubulipora verrucosa.
Part of a stock (magnified); *b*, A few cells (highly magnified); *c*, A stock (nat. size).

The moss-animals seem to be exceptionally rich in methods of reproduction. There is, firstly, the sexual reproduction above mentioned; secondly, the multiplication of individuals by budding and stock formation; and, thirdly, a peculiar reproduction, found in fresh-water forms, in adaptation to external conditions, enabling the animals to tide over the cold of winter, or the drying up of ponds, etc. This last method deserves description. It is effected by means of germinal bodies, which may be of two kinds. In the genus *Paludicella*, the germs are produced in the course of a few days at the end of September by simple constriction or breaking off of portions of the stock, which then perishes. These detached portions vary greatly in size, and resemble buds of the same size, which latter however remain connected with the stock. They are, in fact, detached buds, called winter-buds, which adhere to the dead remains of the horizontal creeping stem of the *Paludicella* stock, and the next spring either grow out at the same place into new colonies, or are swept away by the water to form fresh colonies at a distance. The other germinal bodies, termed statoblasts, form as cell-masses on the strand known as the funiculus, which holds the stomach in place, also at the end of September. They are round or oval in shape, and become surrounded by a peculiar horny transparent shell, which is brown or yellow in colour, and consists of two valves fitted one upon the other like watch-glasses. A number of these statoblasts may be seen inside the colony in the illustration on p. 425. The edge running round the two valves is often widened and contains small air-chambers, or else horny filaments which stand out radially and have barbed tips. This ring is termed the swimming-belt, and is a hydrostatic apparatus, which supports these winter-buds or statoblasts on the surface of the water. The complicated barbed hooks apparently act as anchors, by means of which the passively swimming statoblasts catch on at points suitable for their development during the course of the next spring. As soon as the time for development comes, the two valves split apart, and the germinal mass emerges from between them. Here, then, we have an alternation of generations. Out of the winter-buds and statoblasts asexually produced individuals arise, which then reproduce themselves sexually, their descendants again

yielding winter-germs. The colony produced from the winter-buds may, however, continue for some time to multiply sexually, but in autumn again produces statoblasts. These processes taken together, namely, the growth of a Bryozoan colony by means of the budding of one individual out of another, the detachment of the winter-buds in *Paludicella*, the formation of the statoblasts, and the appearance of eggs, well illustrate the close connection existing between growth and reproduction.

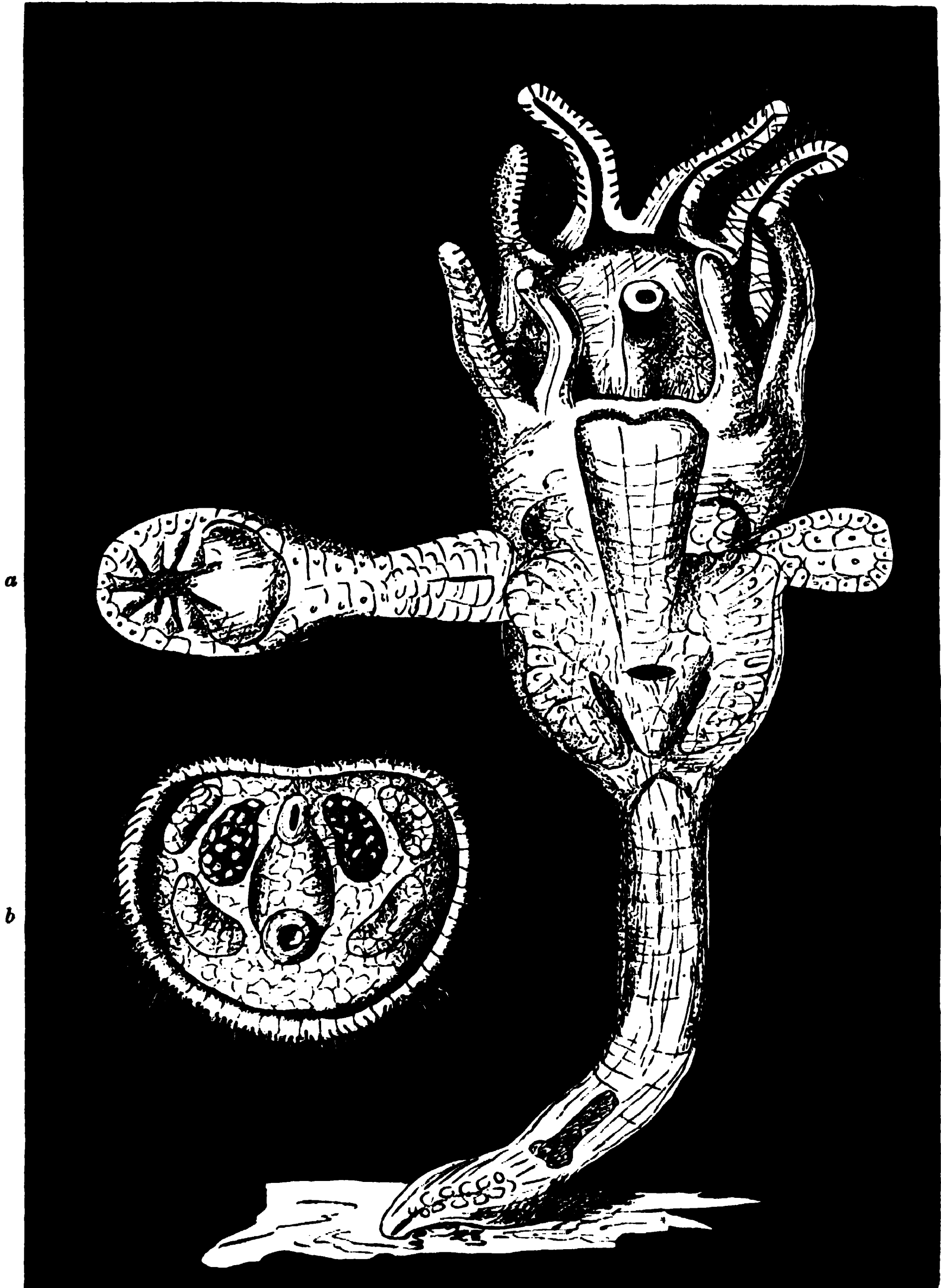


a, Cristatella (double the nat. size); *b*, STATOBLASTS OF *Cristatella*, WITH THREE YOUNG ANIMALS (enlarged).

Subclass Endoprocta.

Systematists have hitherto found themselves compelled to add to the Bryozoa, or moss-animals, certain genera whose most striking peculiarity is that the posterior aperture of the alimentary canal lies within the tentacle-crown. These have been called Endoprocta, in contradistinction to the Ectoprocta, in which, as we have seen, the aperture of the intestine (*c* in the illustration on p. 420) lies outside the tentacle-crown. We take, as an example of the Endoprocta, the genus *Loxosoma*, which might well be called the spoon-animal, since, not only in *Loxosoma cochlear*, represented in the illustration on p. 426, but in most other species as well, the side view, especially when the tentacles are withdrawn, strikingly recalls a ladle. The body is attached to a stalk, and its anterior portion carries a circle of from eight to twelve tentacles, provided with double rows of long cilia. The mouth is at the lower edge of the disc which carries the feelers, while the posterior aperture of the digestive tract lies somewhat above the middle of the disc. The thick stalk is well provided with muscles, and is attached by means of its foot or sucker-like end, to the point chosen by the animal, so as to be fixed by the probably viscid secretion of a large pedal gland. The whole animal is more or less transparent, and leads a retired life in the sea, often hidden in the cavities of horny sponges. Although capable of slow locomotion, *Loxosoma* appears seldom to move from the place once chosen. It feeds on microscopic particles, brought by the stream of water kept up in the cavities of the sponge it inhabits. This food is conducted to the mouth by the cilia of the tentacles and by a ciliated furrow round the tentacle disc. The method of reproduction of this animal is remarkable. Two lateral buds are seen on the mother in the illustration on p. 426. The young animals quickly and without any metamorphosis attain the form of the parent, and may, even while attached to her, feed independently, only falling off when mature, and becoming attached in her neighbourhood. This is

not, however, the only manner of reproduction. From time to time, without any interruption in the lateral budding, fertilised eggs ascend from the ovary towards the tentacle-disc, and develop into larvæ which in no way resemble *Loxosoma*



A FIXED MOSS-ANIMAL (*Loxosoma*) WITH LATERAL BUDS (×200). *a*, Stock ; *b*, Swarm-larva (×100).

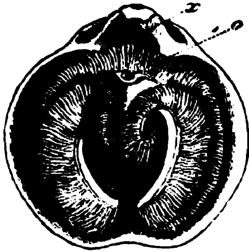
They have flat, almost shield-shaped bodies, surrounded by a ciliated margin. After breaking out through the disc of the mother, at the stage represented in the illustration, they pass through various changes before reaching the adult form.

The Lamp-Shells,—Class **Brachiopoda.**

We must now leave the moss-animals, about whose relationship to the rest of the animal kingdom we know so little, and pass on to the equally enigmatical class of the arm-footed animals, or Brachiopoda. The chief structural feature in the Brachiopods which led to their being classed as molluscs, was their bivalve shell. They were therefore regarded as a subdivision of the bivalves. How easily a Brachiopod might be mistaken for a mussel will be understood by the reader who glances at the accompanying illustrations. But whereas the shells of the mussel are at the animal's sides, and close in front, behind, and below, the hinge being on the back, in the Brachiopods one shell is on the back and the other underneath. There are, in addition, other profound differences in the anatomy of the soft-parts. A further argument against there being any relationship between the Brachiopods and the mussels is found in the fact that no intermediate forms exist which could facilitate the deduction of the one class from the other. On the other hand, many zoologists are inclined to consider the Brachiopoda to be modified worms, a view confirmed by their anatomy. Although there is little to record of the activities of these creatures, they are worthy of attention, not only on account of their structure, but also from their extraordinary stability. With regard to this latter point they are almost unique in the animal kingdom (if we omit the lowest unicellular organisms), in having remained essentially unaltered from the earliest geological epochs. They have neither progressed nor degenerated, but have lived on practically at a standstill, so far as organisation is concerned. The period in which they flourished most is now long past. Not only in the number of species, but also in the number of individuals were they once so rich that thick layers of rock have been built up by their accumulated remains. Brachiopods are divided into two orders; those having shells without hinges, and those with shells hinged together. Taking the latter order (Testicardines) first, a few of its most important families may be described.

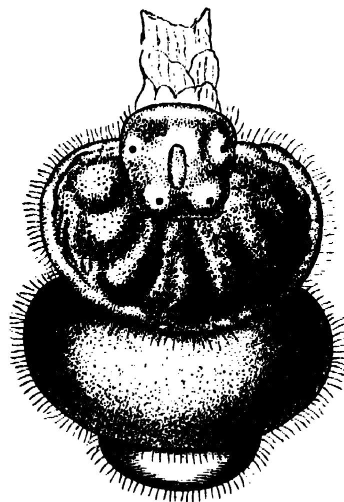
Hinged Group. At the present time, the most widely spread group are the *Terebratulidæ* or perforated Brachiopods, to which *Terebratulina*, figured on p. 428, belongs. In all species of this family, the dissimilarity of the two shell-valves is strongly marked, one valve being larger than the other, more concave, and perforated at the beak. The hole through the beak in this family resembles in some cases the hole for the wick in an ancient lamp, and has thus led to the name lamp-shells being applied to all Brachiopods. Through the perforation a short sinewy stalk emerges, by means of which the animal attaches itself to submarine objects. The hinge at the beak consists of a pair of teeth situated on the larger valve, and fitting into depressions in the smaller valve. Thus, although these shells do not possess an elastic band or ligament, like that which binds together the shells of a mussel, they are prevented from falling apart. The valves are shut and opened by means of muscles. In consequence of the position of the animal and of its organs, the larger more concave valve has been called the ventral valve, and the smaller the dorsal valve or lid. The most remarkable feature in these ancient forms is the looped calcareous framework attached to the under surface of the lid near the hinge, and running forward towards the gape of the

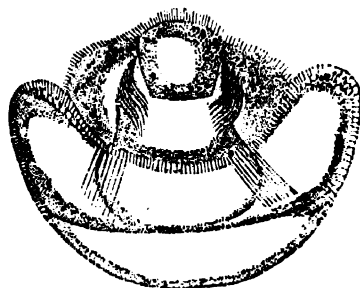
shell. The differences in the forms of this framework are used for distinguishing the families and other subdivisions of the Brachiopoda. Its form and extent can be made out in well-preserved fossil specimens. These two spirally coiled appendages are the "arms," from which the class takes its name, and deserve a little closer description. The illustration below represents the under surface of a valve of the serpent-headed *Terebratula*, near the back of which the mouth opens (*o*). The arms rise on each side of the mouth, run forward, bend back again, to end in an elegant coil. We may compare them to the crown of tentacles and other organs associated with the mouth of many worms, and of the moss-animals, only here they are stiffened by a calcareous skeleton. As can be gathered from their rigid calcareous frame, they are capable of only slight movement, and even their fringes are more or less stiff. As to the functions of these arms, inasmuch as they are traversed by canals, and covered with cilia, we are justified in assuming them to be gills. The animals feed on fine particles brought to the mouth by the streams of water set up by the cilia on these gills. In only one genus (*Rhynconella*), belonging to the family of the *Rhynconellidæ*, do the arms themselves project beyond the shell to seize prey. The alimentary canal is short, and ends blindly at *x*. The body of the animal within the shell is enveloped in two mantle-folds closely applied to the shell; the latter being formed by a secretion from the outer surface of this mantle. Very simple reproductive organs lie in vessel-like widenings of these mantle-folds. The sexes are separate, and may sometimes be recognised by differences in the form of the shell. A pair of membranous funnels, internally ciliated, serve as ducts for the genital products; the free ends of these funnels open into the body-cavity, and conduct the reproductive elements outwards. The resemblance of these funnels to the nephridia of worms, would hardly be enough to establish a relationship between the Brachiopods and the worms. Their relationships rest rather upon the developmental history of the Brachiopods and the transformations they undergo. The first stages in the development of *Thecidium* are briefly as follows. The developing eggs enter a pouch formed by the lower mantle-fold, into which also the two nearest arm-fringes sink. These latter become thicker, their ends swelling to form a pair of pads, round which the eggs group, and to which each embryo is attached by means of a short stalk. The embryo soon resembles a short thick annelid. The upper process from its neck is the stalk by means of which the embryo is attached to the arm-fringe. The small anterior section resembles a head, and carries four eye-spots and a depression, the future mouth. There are two thicker middle segments, followed by a fourth smaller segment, all covered with cilia. In the later development the most posterior part is used for attachment, the head and collar-like ring sink between the upward growing portions of the following ring. These upward growths increase and form the two mantle-folds. These, as above stated, secrete the shell. The illustration (*b*), shows the young *Thecidium* withdrawn into itself, having given up the free-swimming life it led after breaking away from its parent.



BACK VALVE OF *Terebratulina*, SHOWING THE ARMS.

The developmental transformations of another genus, *Argiope*, are very instructive. Its larva may not only be compared with that of a bristle-worm; it is in reality such a larva. No further development, however, occurs in this direction, but rather a degeneration. It becomes transformed into a creature which has no resemblance to an annelid. The posterior end changes into a stalk, by means of which the animal is permanently attached, while the bivalve shell protects the otherwise defenceless body. In this case we can witness the degeneration of an animal in its own development. It begins as if it were going to be a highly developed worm, which seems to show that its ancestors were once such worms, but it disappoints us; instead of advancing in organisation, it suddenly drops back into the lowly creature described. Off the coast of Norway, the serpent-headed *Terebratulina* is found everywhere in small numbers, at a depth of from thirty to one hundred and fifty fathoms, often attached to the coral *Oculina*. When placed in sea-water, they gradually open their valves; those specimens which remain attached to foreign objects show a great disposition to move about at the ends of their stalks. Detached specimens can be moved about without causing the animal to close its valves. If some of the protruded cirri be touched, they are at once withdrawn and the valves snap together, but soon open again. When the arms are withdrawn the cirri are bent inwards, but when the valves open the former are seen to raise themselves into an upright position; even before the shell was opened a few cirri were often protruded and waved to and fro, as if to ascertain whether any danger threatened. An inflowing current of water can sometimes be observed between the two rows of cirri.

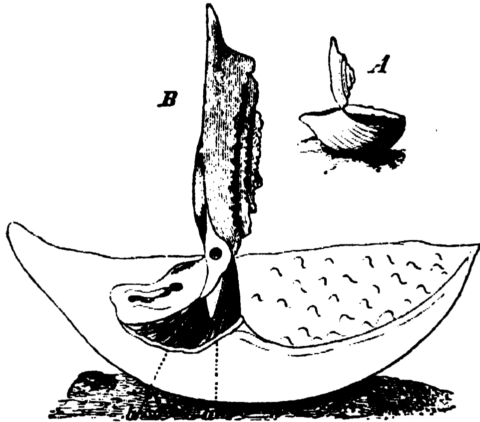




STAGES OF DEVELOPMENT OF *Thecidium* (magnified).

Another form, *Waldheimia cranium*, is found near the North Cape, at a depth of from twenty-five to one hundred and fifty fathoms, attached to stones or barnacles. The calcareous framework in *Waldheimia* is long, and the oral appendages are incapable of movement unless it be at their spirally coiled ends. It has been conjectured that the two coiled ends can be unrolled and rolled up again like the proboscis of a butterfly. These animals are more active than *Terebratulina*, frequently moving about on the ends of their stalks and being more easily alarmed. The cirri do not project beyond the edge of the shell, and are bent back when it is closed. The genus *Thecidium*, whose development is described above, is distinguished by the very peculiar calcareous framework of its arms; one of its few living representatives being the unstalked *T. mediterraneum*, figured on p. 430. In this form the dorsal valve forms an almost flat lid for the much larger ventral valve, and is seen in the figure standing wide open at right angles to the lower shell. The

calcareous framework nowhere rises freely from the lid, with which it is connected by a calcareous network. In the section (*B*) given in the illustration we see in the dorsal valve the depression for the hinge on which the valve rotates. The shell is opened by the muscles (*b*) which run from the bottom of the ventral valve to a process directed backward in the dorsal valve behind the hinge. It is closed by the muscles marked *a*, which lie in front of the hinge. The shells of *Thecidium* become attached to submarine objects, and are brought up in considerable numbers by the nets of the coral-fishers between the Gulf of Bona and Cape Rosa, from a depth of from forty to fifty fathoms. The number of specimens of *Terebratula* is small as compared with that of *Thecidium*, twenty to thirty specimens of the latter being often found together. When first caught, *Thecidium* opens its valves very wide, but when isolated and placed in small vessels gapes less widely. The small dorsal valve or lid can be raised to form a right angle with the other valve, but, when the slightest movement is made, it snaps to with the speed of lightning. These lamp-shells are undoubtedly sensitive to light, even a shadow thrown upon them making them close their shells instantly. On account of the wide gape, the inner organs, such as the cirri and arms, can be accurately observed. The inner surface of the shell on which the mantle lies is so dazzlingly white, and the latter so transparent, that the calcareous framework and the prominences on the valve are as easily seen as if there were no intervening mantle. Externally, the shell is rarely white and smooth, being usually covered with plants or animals which have attached themselves to it, and the valves perforated in all directions, chiefly by boring sponges.



Thecidium mediterraneum. *A*, Nat. size ; *B*, Section through the shell (magnified).

The *Rhynchonellidæ*, or beaked Brachiopods, were extremely numerous in the oldest geological times, but are now only represented by some three genera. The most important genus is *Rhynchonella*, which is one of the oldest and most widely distributed of all known organisms, being found from Silurian times through all subsequent strata. The living *R. psittacea* shows best the characteristic beak-like process of the ventral valve ; the aperture for the stalk being found under this beak. The valves are fastened together as in the *Terebratulidæ*, but the calcareous framework consists merely of two short, narrow plates, which are attached to the smaller valve. *Rhynchonella* is not very numerous in northerly regions, but empty valves are found in mud. Observations on the living animal are rendered difficult by the fact that it is peculiarly sensitive to all disturbance, and closes its valves at the slightest movement. The arm-spirals widen sufficiently to allow the cirri to reach the edge of the shell ; the arms do not appear capable of unrolling and protruding beyond the shell. The members of another family of this order of hinged Brachiopods, the *Spiriferidæ*, are rendered

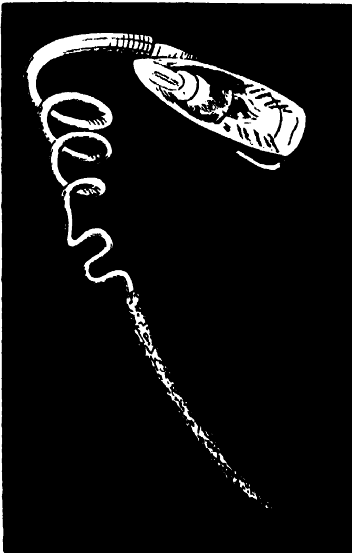
very remarkable by the long, spirally-coiled and calcified arms. *Spirifer* was very abundant in the Palæozoic epoch, but died out with the Lias.

Hingeless Group. The second order of the Brachiopods (Ecardines), or those whose shells are without hinges, consists of but four families, two of which may be briefly described. The unstalked genus *Crania* is widely distributed, both geologically and at the present time. Its structure is so peculiar that it forms a family by itself (*Craniidæ*). The shell is attached to some submarine object by the ventral valve; the dorsal valve is lid-like, and the two valves connected, not by a hinge or interlocking processes, but simply by muscles. The best-known of the four living species (here figured) of the northern seas, is almost always found in company with *Terebratulina,* which, however, it does not follow into the seas of Northern America.



UPPER VALVE AND ANIMAL OF *Crania* (magnified).

The last family to be described, the *Lingulidæ,* is also one of the most interesting. It existed in the oldest fossiliferous strata, and is still found living chiefly near the shores of the warmer seas. It may be regarded as perhaps the very oldest of the Brachiopods. Indeed, if we may look upon the hinge which characterises the other order as a specialisation, the hingeless forms are clearly the older and more primitive. The shell of a *Lingula* is thin and horny, almost flexible, and green in colour. The valves are almost exactly similar, and, as we have seen, they are not hinged together; and, further, they have no processes for the support of the thick, fleshy spiral arms. No living *Lingula* is now found in European seas, but *L. pyramidata* occurs on the American coasts, and another, *L. anatina,* in the Philippines. The stalk of the former, which is nine times as long as the body, does not become attached, but moves like a worm, and again, like certain worms, makes tubes out of sand into which it can withdraw. The *Lingulidæ* generally live in holes in mud, the bottom of which is lined with sand. The shell-covered body projects above the mud to open and feed; on being alarmed, it shuts and disappears below the surface. The cilia at the mantle-edge form a fine sieve which prevents foreign particles from entering the gills. The length of life of *L. pyramidata* is not more than a year. The simplicity of the shell of *Lingula,* which may best be compared with the cartilaginous structures at the anterior end of a chætopodous annelid, and its occurrence in the oldest strata in which Brachiopods are found, seems to justify the conclusion that it stands nearest of all the class to the worm-like ancestor.



Lingula pyramidata (nat. size).

H. AND M. BERNARD.

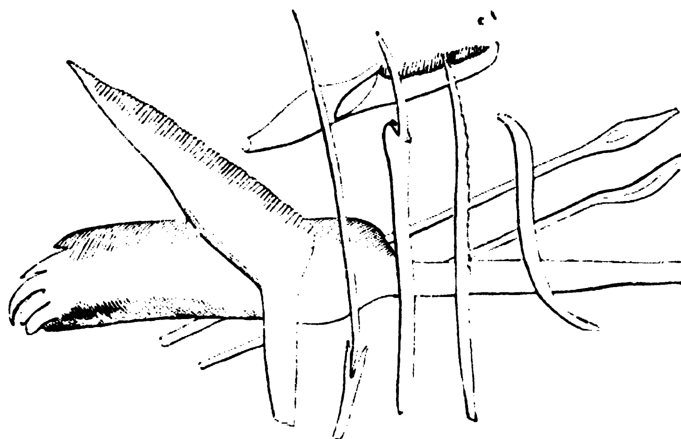
CHAPTER XIII.

THE WORM-LIKE ANIMALS,—Subkingdom **VERMES.**

ALTHOUGH it is convenient to have a single group in which to include the various kinds of worm-like animals, it has been frequently pointed out that there is no natural sanction for such an arrangement, and that it is highly probable they ought to be divided into several subkingdoms. Accordingly, the present division of the animal kingdom must be regarded as a convenient receptacle in which to place such Invertebrates as cannot be readily assigned to any of the other subkingdoms. This being so, it will be evident that it is only possible to describe this assemblage of heterogeneous elements by stating that the various classes into which it is divided resemble each other in the negative feature of not possessing the characters distinctive of any of the other groups.

BRISTLE-WORMS, OR ANNELIDS,—Class **Annelida.**

The more highly organised members of this group show unmistakable points of affinity with the arthropods, such as *Apus* amongst the Crustacea, and *Peripatus*, which approaches the Centipedes. It is possible, however, to mention certain characters, which, so far as known, serve to distinguish the bristle-bearing worms from the arthropods. In the worms the jaws, when present, are not modified appendages, but are merely horny skeletal pieces developed from the walls of the front end of the alimentary canal; the appendages, when present, are not segmented, but merely unjointed processes of the sides of the body, and certain parts of the body are ciliated, or beset with fine hair-like threads, such threads being seldom found at any stage in the life-history of an arthropod. To distinguish the annelids or chætopods from the groups that follow, it may be said that there is usually a distinct prostomium, or lobe in front of the mouth, that definitely arranged bristles are implanted in

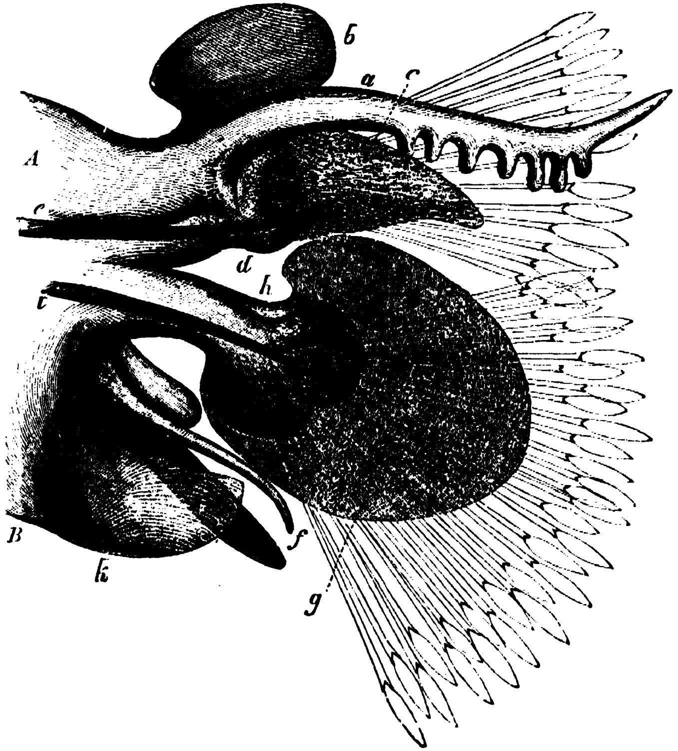


GROUP OF BRISTLES OF AN ANNELID (enlarged 100 times).

the segments of the body, and that the latter are defined externally by transverse grooves, and internally by septa or partitions, which divide the body-cavity into a series of compartments.

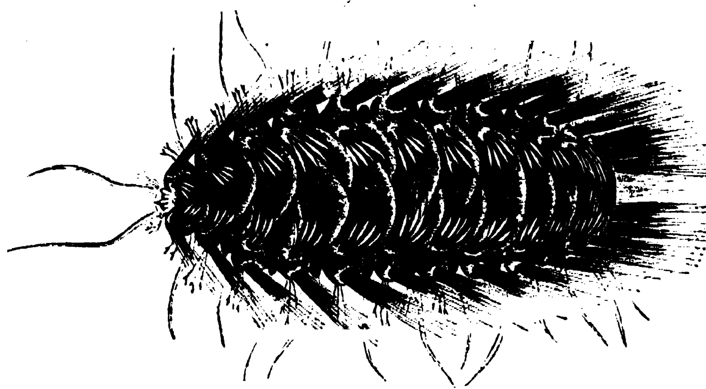
MANY-BRISTLED GROUP,—Order POLYCHÆTA.

The Annelids of this order live exclusively in the sea, and may be referred to two sections or suborders, the one being the wandering or roving species, which have no fixed abode (Errantia), while the other sedentary forms live habitually in tubes which they construct for the purpose. In the former of these two suborders in accordance with the free roving life, the front end of the body is furnished with a conspicuous lobe, or prostomium, overhanging the mouth, which bears eyes and feelers. Those forms that are carnivorous seize their prey with sharp-hooked teeth, visible at the end of the proboscis. The structure of one of the parapodia is shown in the accompanying figure. It consists of two principal branches, an upper (*A*) and a lower (*B*), each being supported by a long stout bristle (*e*, *i*). The branches are further divided into several well-defined parts. For instance, in the upper there is a conspicuous feeler or sensory cirrus (*a*), and a bilobed leaf-like plate (*b*, *c*), from the lower lobe of which (*c*) projects a cluster of arrow-shaped bristles. Analogous parts may be recognised in the lower branch, *f* being the feelers, at the base of which is the leaf-like plate (*k*); while the larger leaf-like plate (*g*) supports a second and larger tuft of similarly-shaped bristles. A well-known example of this group is the sea-mouse of the British shores (*Aphrodite aculeata*), a broad-bodied, somewhat slug-shaped creature, commonly 3 or 4 inches in length. Like many of the species of marine worms the sea-mouse is ornamented with iridescent hues, revealed by cleansing the skin of the mud and sand with which it is usually coated. The back is furnished with a double row of large overlapping scales, but in the British species these scales are concealed by a close felt of hairs, although in another kind

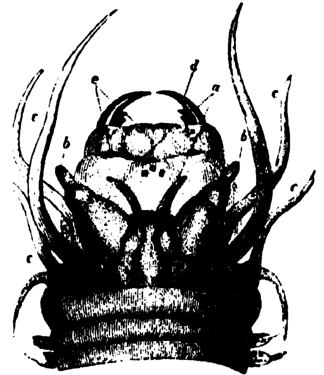


PARAPODIUM AND BRISTLES OF A POLYCHÆTOUS ANNELID, *Heteronereis œrstedi* (much enlarged).

(*Hermione hystrix*), common in the Mediterranean, this coating of hairs is absent, and the scales are exposed, as shown in the accompanying illustration. In spite of their thick armature of spines, all the sea-mice are greedily devoured by fish of various kinds, such as cod, haddock, and dog-fish. Another well-marked family is that of the *Nereidæ*, in which the predatory character, coupled with ceaseless activity, rapidity, and sureness of movement reaches its highest expression. The head of the particular species (*Nereis incerta*) represented in the illustration shows two pairs of feelers (*a* and *b*), as well as several pairs of longer organs of the same nature (*c*), situated at the sides of the head. On the thrust-out and upturned proboscis may be noticed the two strong, sharp-toothed jaws (*d*) as well as several smaller horny teeth (*e*). In the worm named *Heteronereis*, which is shown at *A* in the next illustration, one of the chief peculiarities is that the segments in the hinder half of the body are not so high as those in front, and that they are furnished with far longer bristles, whereas in *Nereis* all the segments are alike, being constructed on the same plan as those of the front half of the body of *Heteronereis*. The exact nature of the connection between these two marine worms does not appear to be understood. The latter, however, seems to be a stage in the development of the former; but not an invariable stage, since adult examples of *Nereis* produce young sometimes like themselves, and sometimes like *Heteronereis*. Allied to the *Nereidæ* is *Palolo viridis*, of the Samoa Islands. Of this species Stair and Powell write that "every year the animal appears during October and November in countless numbers at different spots on the coast; but the second swarm is even greater than the first. . . . Both swarms seem to make their appearance on the day before the last quarter of the moon, and on this day, but especially on the day of the last quarter itself, the crowd of them is so inconceivably great that the sea, even far from the shore, seems to consist of nothing else. The worms appear with the dawn of light, and their number is at its height by sunrise, but after two or three hours all have vanished." Curiously enough this mass of worms seems to be composed entirely of living fragments, entire examples being never met with.



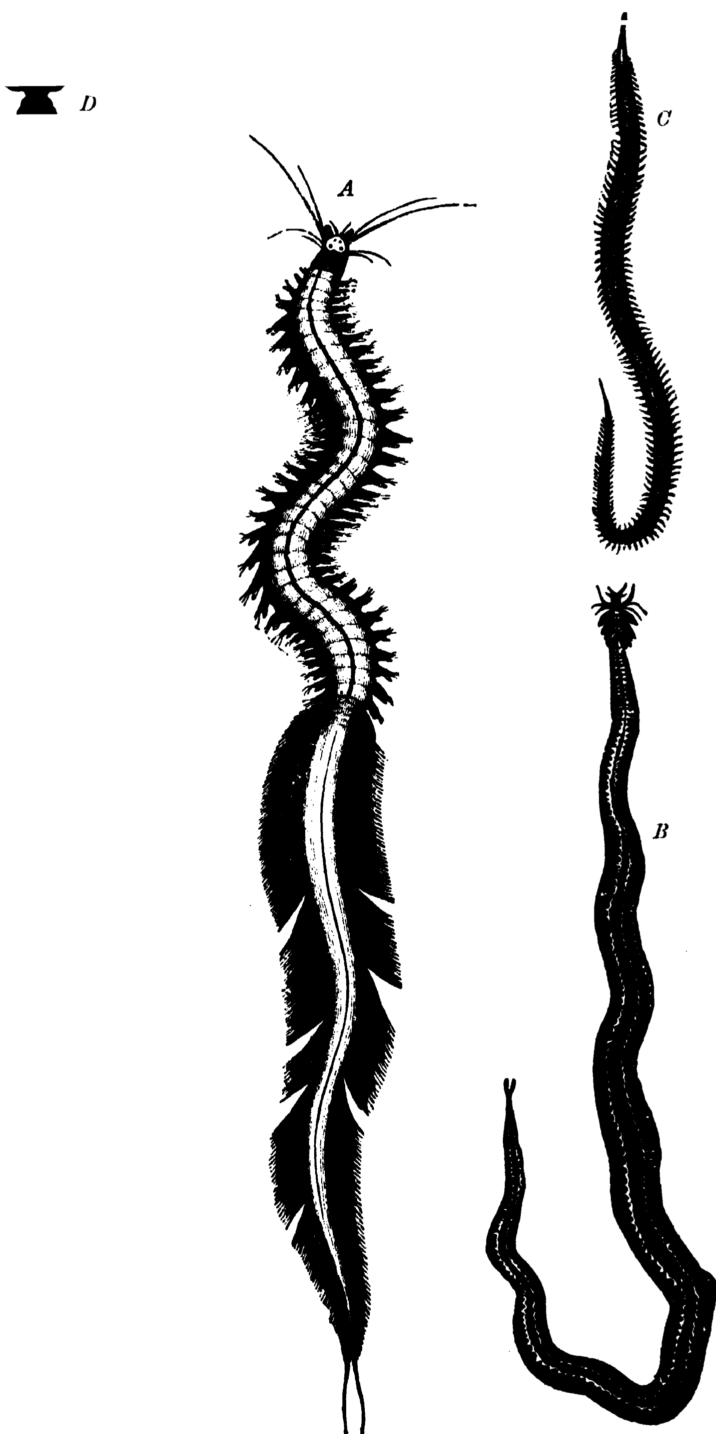
SEA-MOUSE, *Hermione hystrix* (nat. size).



HEAD OF *Nereis incerta* (enlarged 4 times).

Two more types of roving predatory worms are shown in the same illustration. Of these, *Phyllodoce laminosa* of the French and English coasts has as many

as three hundred to four hundred segments, and may measure as much as 2 feet in length; the parapodia are flattened and leaf-like. During the day these animals lie quietly in their hiding-places, but come forth at twilight to swim about in search of prey, when the whole body, supported and in part propelled by the parapodia, executes the most graceful wave-like movements. *C* shows a species of the genus *Glycera*, a comparatively dull coloured form, which habitually lies hidden in sand. These worms make their burrows by means of their relatively colossal proboscis, which is studded with numerous little warts and teeth. From the genus *Glycera* there is naturally a passage to the sedentary group (Tubicola) of polychætous annelids, and we may take as our first example the sand-worm (*Arenicola piscatorum*), represented of the natural size in *D* of the illustration. This worm reaches a length of about 8 inches. Individuals vary, however, much in colour, according to the nature of the mud or sand in which

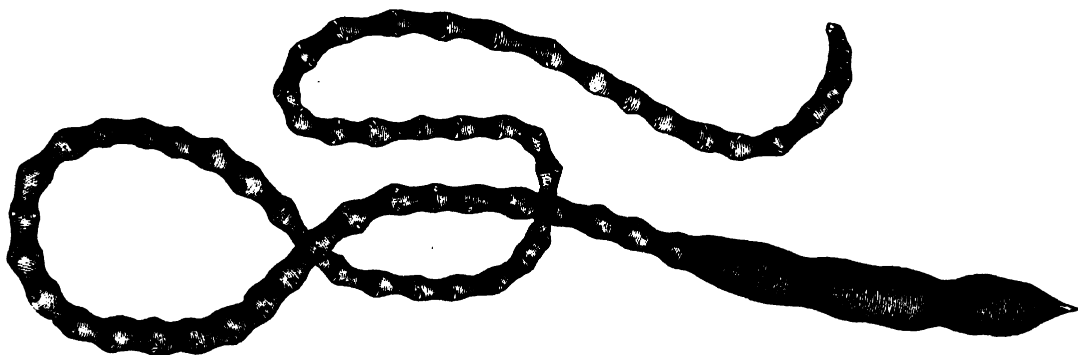


VARIOUS ANNELIDS.

A, *Heteronereis* stage of *Nereis*; *B*, *Phyllodoce laminosa*; *C*, *Glycera*; *D*, Sand-worm or lug-worm, *Arenicola piscatorum*. (All nat. size.)

they are found; those living in clean sand being of a light tint, whereas black specimens frequent slimy sand, strongly impregnated with decaying organic matter. The segments of the body are not all alike; those at the front end being furnished with a few small, widely-separated tufts of bristles arranged in pairs; then follows a series in which the clusters of bristles are large, bush-like, and close together; while the end of the body is cylindrical and without bristles and parapodia. The goblet-shaped organ, shown in the illustration, projecting from the head is the protruded proboscis. This worm, which is found on all the coasts of Europe, is used by fishermen as bait. At low water, on some sandy shores, it may be found in vast numbers.

In the family *Clymenidæ*, to which belongs the worm known as *Arenia fragilis*, the body is only divisible into two regions. The fore-part, which is of a dirty red tint, alters its shape greatly owing to the retraction and extension of its

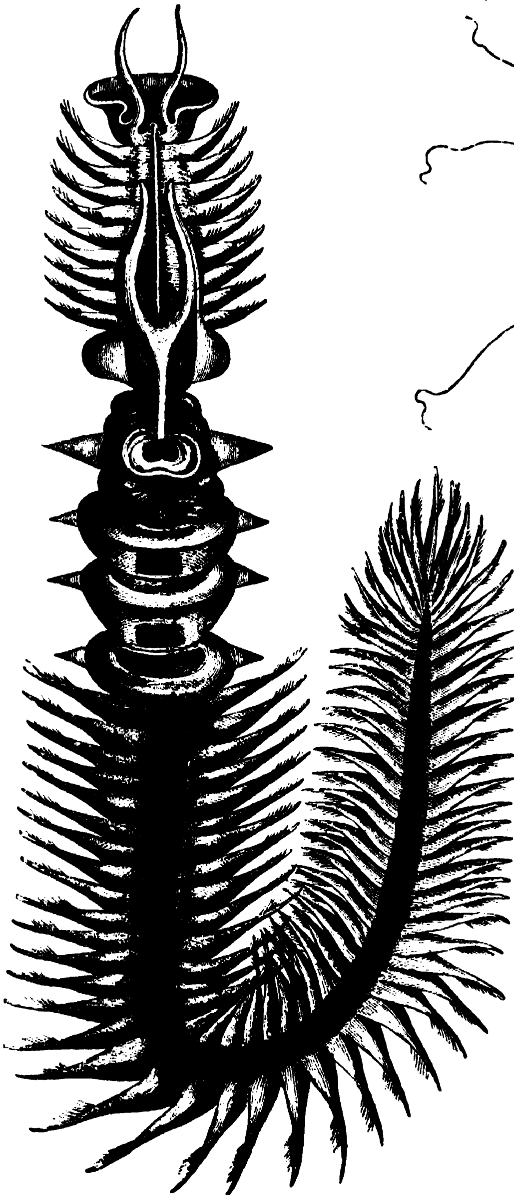


Arenia fragilis (nat. size).

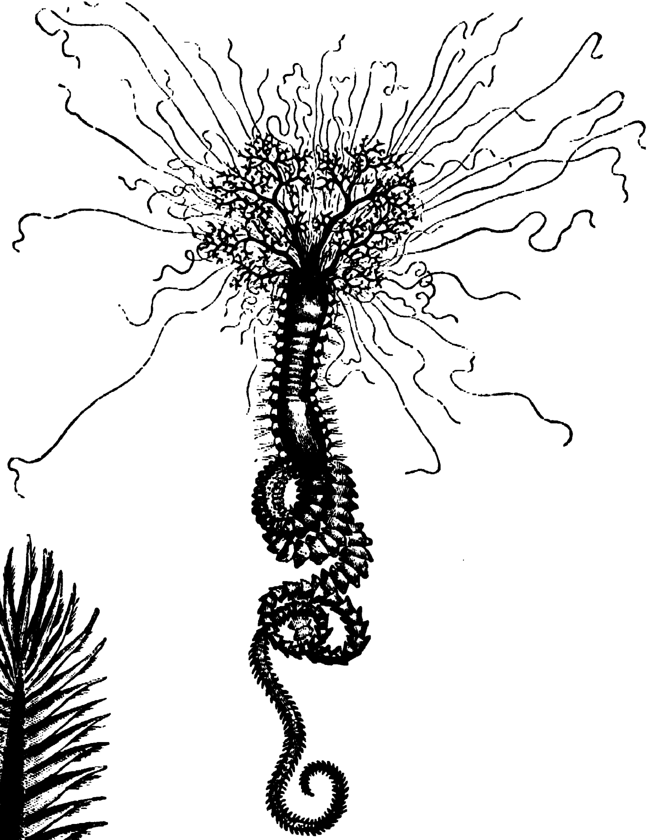
segments; while the exceedingly long and slender hinder part is of a yellowish colour. A remarkable family is that of the *Chætopteridæ*, containing the genus *Chætopterus*, of which a specimen is represented of the natural size in the illustration on p 437. The head is funnel-shaped, with an indentation on its upper side, and from this spring a pair of feelers. The body is marked out into three regions; the most striking being the formation of the five segments which compose the middle region of the body. From the first segment of this area the parapodia stand out like a pair of flat feelers, while the lower branches of these feet are spread like a ruff over the abdominal region. The upper branches of the parapodia of the second segment unite with those of the first to form a dorsal crest, and between these and the lower branches the skin is much swollen and of a violet colour; the following three segments are swollen and have relatively short parapodia. Species of these worms are found on the coasts of Normandy and in the Mediterranean. Like many other marine animals, this worm is phosphorescent, the phosphoric matter spreading like a cloud in the water.

In the next group the gills are in the form of small trees or branches of threads attached to the end of the head; while the mouth is unprovided with either teeth or a proboscis. The creatures spend their days in tubes, from which they can only be extracted by force. In *Hermella* the body ends in a long unjointed, limbless, hairless tail, while the rest of the body bears well-

developed bristly parapodia, upon the upper side of each of which there is a tongue-shaped gill. The head is remarkable in that the two large feelers blend



Chætopterus.

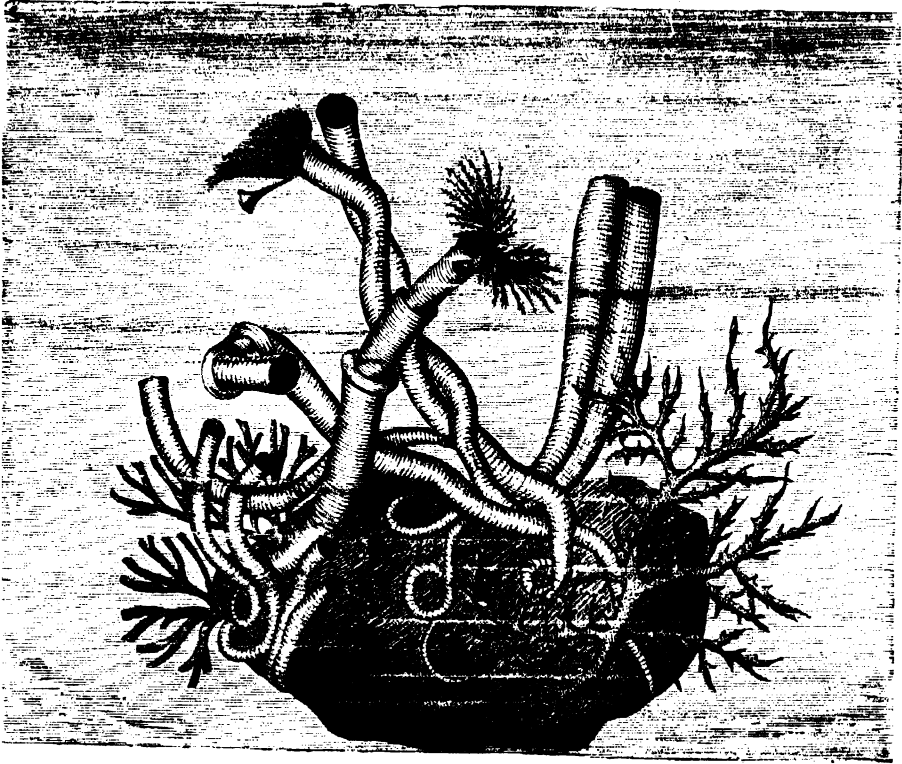


TUBE-WORM (*Hermella*).

into one and bear a few rows of broad, flat bristles. They are thus converted into a stopper, which closes the mouth of the tube when the worm is retracted. In *Terebella*, forming the family *Terebellidæ*, the tubes are formed of fragments of sand or shell.

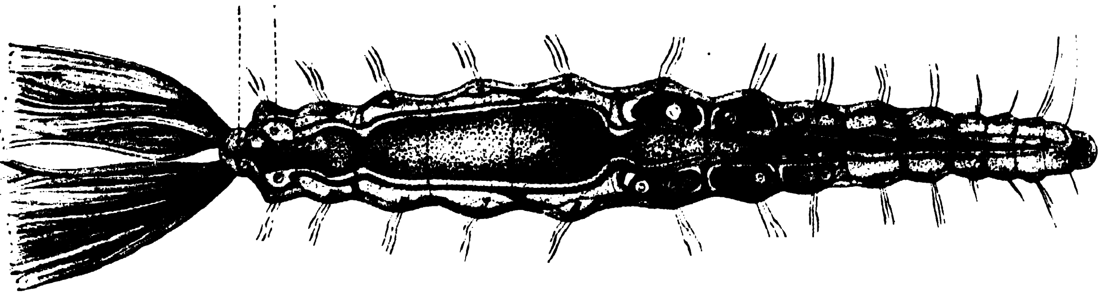
In the family *Serpulidæ* the gills are restricted to the fore-part of the body, and the water set in motion by their glistening hairs brings the food to the mouth, which is situated immediately beneath. The head-lobe is blended with the first segment, and not sharply marked off from it, as in most of the worms hitherto described. These animals live in calcareous (chalky) tubes, the apertures of each tube being closed—when the worm has retreated within—by a tight-fitting stopper, formed from a modified piece of one of the gills. The first tube made by the young worm is cylindrical

and open at both ends, but as the animal increases in size it enlarges and extends its tube by adding on layers of calcareous matter to the aperture at the head-end.



COMMON SERPULA, *Serpula contortuplicata* (nat. size).

The species of the allied genus *Sabella* exude a gluey substance, and construct a flexible, leathery tube. In some cases these tubes are covered with sand, or pieces of shell, and completely resemble those of the *Terebellidæ*. The species of the genus *Amphicora* may be found amongst seaweed on the coasts of Europe.

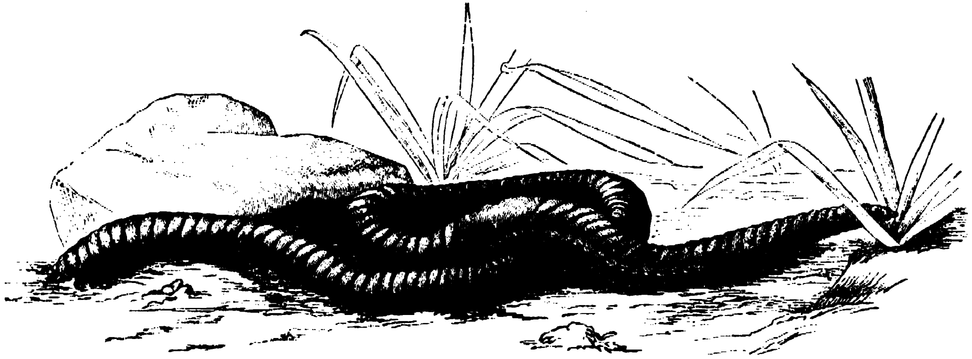


SABELLA, *Amphicora sabella* (enlarged 30 times).

The body is short, measuring less than half an inch in length, and composed of a small number of bristle-tufted segments. Unlike the *Serpulidæ*, the animal habitually leaves its membranous tube in search of food, when it appears as a lively little creature, moving with indifference and facility either forwards or backwards.

Sparsely-Bristled Group,—Order Oligochæta.

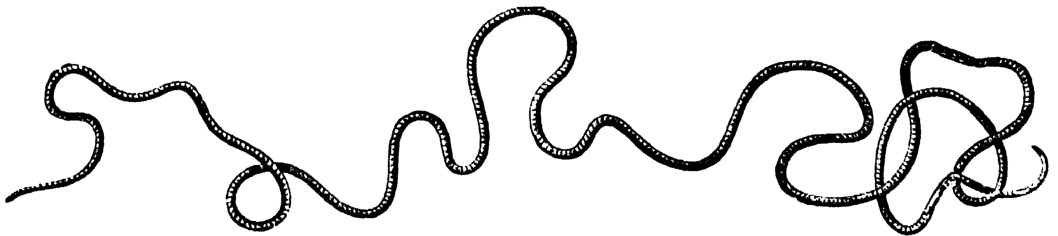
The most familiar representatives of this group are the earth-worms (*Lumbricidæ*), characterised by the numerous short segments of the body, the bullet-shaped, plastic head-lobe, and the hook-like bristles which form either two or four longitudinal rows, and project but slightly above the surface of the skin.



COMMON EARTH-WORM, *Lumbricus agricola* (nat. size).

Apart from certain thickenings of the skin, earth-worms have no special organs of sense, that is to say, neither ears nor eyes, although at the same time they are highly sensitive to the influence of light. Their food consists for the most part of the decaying animal and vegetable matter absorbed from the soil, which they take in large quantities into the alimentary canal; but they also draw into their burrows straws, feathers, leaves, bits of paper, etc., to serve for food. The muscular strength required to overcome such obstacles is often very great, and no one would suppose that a creature so soft, slimy, and to all appearance helpless would be capable of the effort; but the muscular system of these animals is in reality highly developed, as is shown by the strenuous resistance offered to any attempt to drag them from their burrows.

In Britain there appear to be about twenty kinds belonging to three genera, of which the richest in species are *Allolobophora* and *Lumbricus, Allurus* including only the square-tailed worm. Earth-worms appear to be spread over all the tropical



Phreoryctes menkeanus (nat. size).

and temperate parts of the world, and in some countries attain a size far surpassing that of the English species; one of the largest (*Microchæta rappi*) being an inhabitant of South Africa. The average length of this creature is 4 or 5 feet,

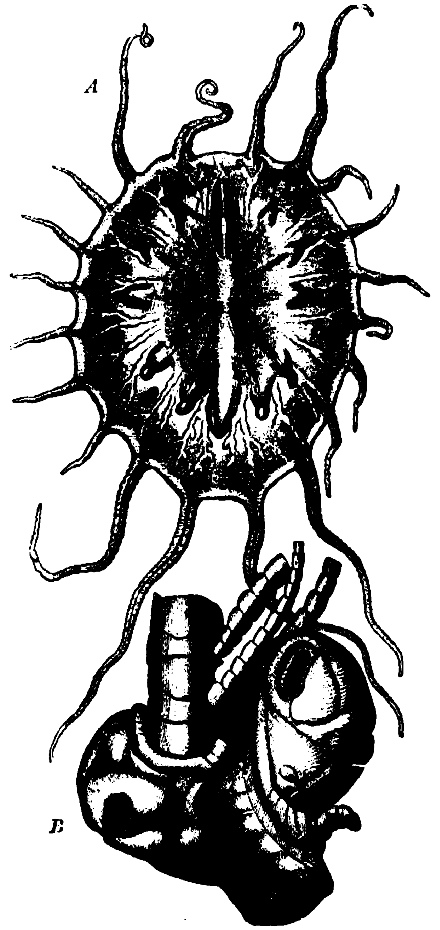
although it is capable of stretching itself much further, and its width is about equal to that of a man's finger. On account of their burrowing habits, worms are not very frequently seen, although periodically—but only after heavy rains—they come to the surface of the soil in some numbers. Allied to the earth-worms is the rare and extremely slender *Phreoryctes menkeanus*, which lives from preference in wells and shallow water, in which it may be found in the greatest abundance in May and June, disappearing in the winter. Another aquatic member of the group is *Tubifex rivulorum*, a small red, translucent little worm, found abundantly on the slimy bottoms of ditches and brooks. These creatures remain with the forepart of the body stuck in the slime, while the hinder end keeps up a continual vibrating movement. Usually they are so closely packed that the surface of the mud appears to be red coloured, and when startled, the whole throng disappears like a flash into the slime. The clear transparent naids behave in quite a different manner. These animals are also found in ponds and ditches, where they may be seen winding themselves in and out amongst the stems of duck-weed. One of the best known is the beaked nais (*Nais proboscidea*), so called from a feeler-like prolongation of the head, which is furnished with two conspicuous eyes. These worms frequently reproduce spontaneously by fission, and it is not uncommon to see one individual in process of giving rise to several others. Amongst the bristle-worms is placed the family *Myzostomatidae*, which was long a puzzle to zoologists. The species are all of small size, the largest, *Myzostoma gigas*, measuring only a little more than a quarter of an inch in length. The body is short and oval. Its upper side, which is variously coloured, is covered with fine threads, called cilia, and its edges are prolonged into ten pairs of long, slender, flexible appendages, while below there are five pairs of horny tipped parapodia, and four pairs of cup-like suckers. All the members of this anomalous family are parasitic upon stone-lilies or crinoids, but the degrees of parasitism are various, some kinds wandering freely about their hosts, while others cause those curious swellings which appear upon the arms of the infested animal.



BEAKED NAIS, *Nais proboscidea* (enlarged 10 times).

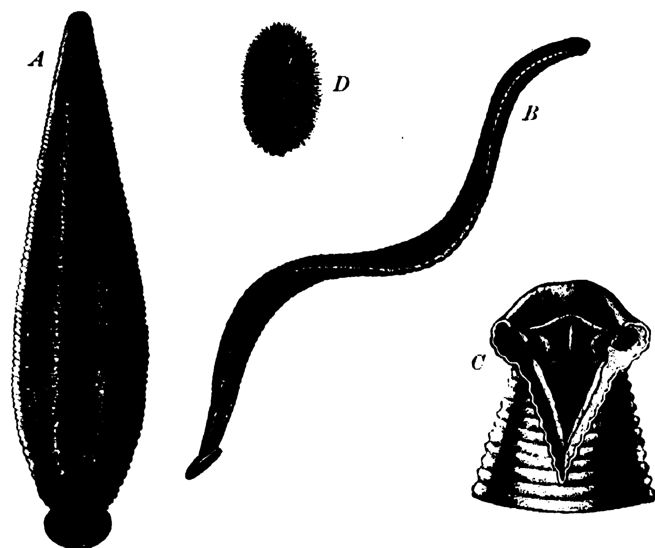
THE LEECHES,—Class **Hirudinea.**

Leeches are worm-like animals which differ from the bristle-worms mainly in the absence of parapodia, and also of bristles, as well as in the presence of one cup-like sucker at the hinder end of the body, and usually of another at the anterior end. Examination of a leech's body shows that the skin is divided into a number of close-set rings. These, however, are not the true segments; for, as the arrangement of the internal organs shows, a true segment of the body—such, for instance, as have been described in the earthworm or the sea-mouse—is composed of four or five of the dermal rings. The best known example is the common leech (*Hirudo medicinalis*), a species in common use fifty years ago for blood-letting. The body is broadest in the hinder third of its length, and from this point it is gradually narrowed towards the head and tail. The head end is furnished with ten eyes arranged in pairs upon the first eight rings. At the tail there is a large cup-shaped sucker with a narrow neck; there is also a second sucker placed upon the head round the mouth, which is armed with three semicircular finely toothed jaws capable of being worked backwards and forwards like a saw. The alimentary canal is of enormous extent and occupies nearly the entire cavity of the body. Its front part, or œsophagus, is a narrowish tube, then follows the stomach which is expanded into eleven pairs of sacs, the last pair of these being very long and stretching backwards side by side with the narrow intestine, which terminates close to the large cup-shaped sucker. The structure of the organs that have been just described explains the utility of the leech as a blood-letter. The creature adheres to the spot upon which it is placed by means of its front sucker, which has the mouth in the middle of it. The jaws are then brought to bear upon the skin and start sawing their way into it, while the blood that flows from the wound passes into the sacs of the stomach until they are all filled; and since the walls of the body as well as those of the alimentary canal are highly elastic, it is easy to understand how the creature is able to expand to two or three times its normal size. Some of the structural points enumerated above are shown in the illustration on the next page, in which 1 is the alimentary canal, with the œsophagus (*a*) and the sacs of the stomach (*b* and *c*); 2 is the head end showing the eye-spots; and 3 is part of one of the jaws.

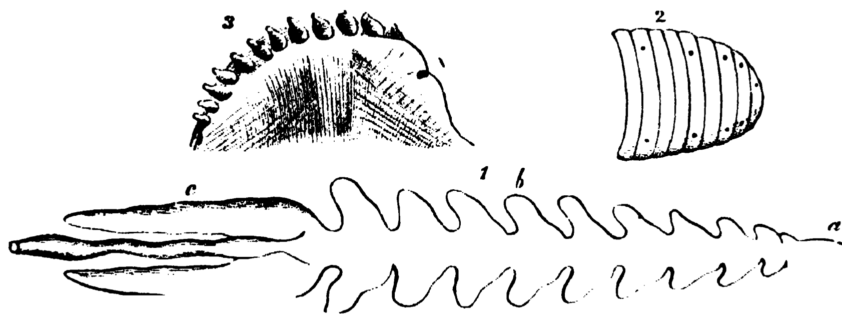


A, *Myzostoma gigas* FROM BELOW; *B*, PORTION OF ARM OF A SEA-LILY (*Antedon*), SHOWING THE SWELLINGS PRODUCED BY *Myzostoma*.

Leeches are found in marshes and ponds with a bottom of mud or clay, and overgrown with weeds. They cannot live long out of water and die as soon as the skin dries, though for some time they may protect themselves from this by the excretion of slimy matter. By day, and especially in warm weather, they swim about with liveliness, but at night and in dark, foggy weather, or on cold days they remain quiet and curled up, and in the autumn they bury themselves deep in the mud. They feed largely upon the blood of fishes, frogs, or mammals, but sometimes, in cases of necessity, devour each other. After pairing in the spring, the suctional leeches bore into the soft spongy ground just above the level of the water, and at the end of July or thereabouts begin to form their cocoons or egg-cases, one of which is shown at *D* in the above illustration. These cocoons are formed of a greenish mucus, or slimy material, and in them from ten to sixteen eggs are laid. The mother then closes the aperture, and over the whole pours out a whitish saliva-like froth, which upon drying forms a spongy coating to the case. The cocoons are placed in the burrows, and from four to six weeks after the laying, the young creep forth. These are thread-like and clear, but like the old ones in form; and appear to attain their full size in about five years, although they may live as many as twenty.



COMMON LEECH.
A, From above (nat. size); *B*, From the side, swimming (nat. size); *C*, Head cut open to show mouth (enlarged); *D*, Egg-cocoon (enlarged.)

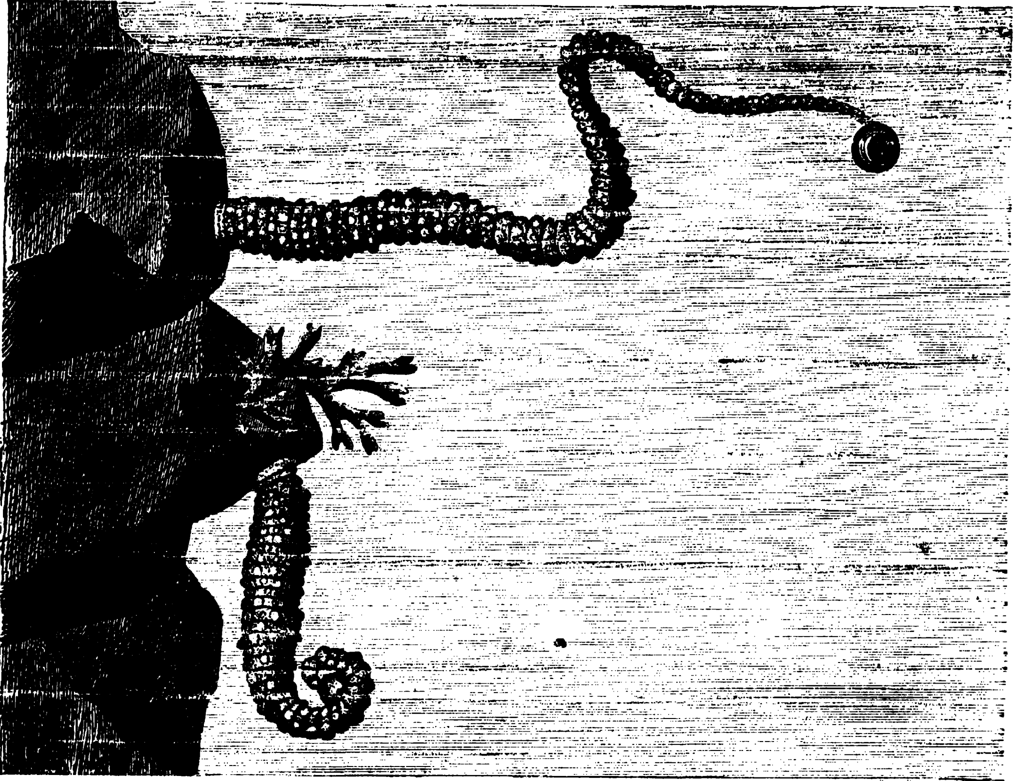


STRUCTURE OF LEECH.
1, Alimentary canal—*a*, Œsophagus; *b*, Saccular stomach; *c*, Last pair of pouches.
2, Anterior end, showing eyes. 3, Jaw.

The colour of the medicinal leech is black above, generally ornamented with pale bands. This species extends over the greater part of Europe, and has been found in France, Germany, England, Russia, and Sweden. Another nearly allied

species, *H. officinalis*, which is of an olive-green, unspotted colour, is most abundant in the south and south-east of Europe. Other kinds are found in Morocco, Senegal, India, and North America. In some parts of the tropics, such as India and Ceylon, land-leeches, which abound in meadows and woods, are a terrible plague. They live on grass or trees, are exceedingly quick in their movements, scent prey from a long distance, and troop in numbers to the spot. Hence a person brushing through the jungle becomes covered with them, unless some precautions are taken.

Another well-known member of the group is the horse-leech (*Aulostoma gulo*), characterised by its blackish green colour, the great narrowing of the fore-



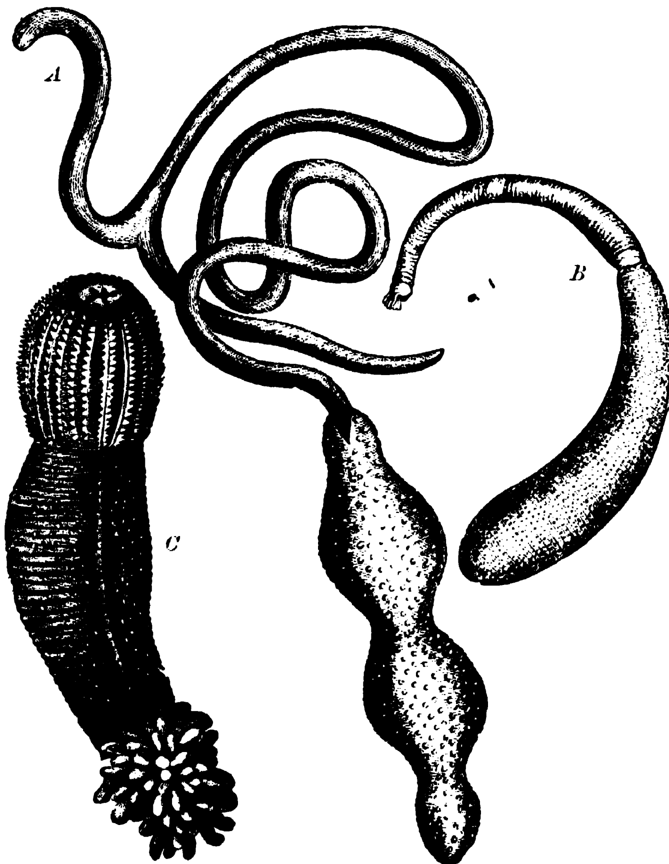
ROCK-LEECH (nat. size).

part of the body, and the presence of only three small teeth in the mouth. Many stories are current as to the dangerous nature of these leeches, and it is even said that nine of them will suck a horse to death; but although doubtless a voracious creature, it is certain that such accounts are fallacious. The horse-leech lives on earth-worms, snails, grubs, and other leeches, and even creeps into the shells of fresh-water mussels, and takes up a lodging there until it has devoured the inmate. Another form that abounds in fresh-water ponds and streams is *Nephelis vulgaris*, which reaches a length of nearly two inches, and has four pairs of eyes and toothless jaws. It appears to feed partly on animal and partly on vegetable food. A second group of the leeches are the *Clepsinidæ*, recognised by the short flat body, which towards the front is usually stumpy, and ends in a seizing disc carrying the eyes. The gullet, which is toothless, can be protruded like a proboscis.

Different species of the genus *Clepsine* may be found on the leaves of water-plants and on the under side of stones. They are grey, yellow, or whitish in colour. Instead of burying their eggs like the medicinal leech, these creatures carry them about, and the young after birth remain some time with their mother. They live principally upon water-snails and young mussels. The engraving on p. 443 represents the rock-leech, *Pontobdella muricata*, remarkable for being an inhabitant of the sea, and also for having the skin covered with warts and knobs. The body, which gradually narrows from the posterior end to the head is of a greenish grey colour, and the anterior sucker large and button-shaped. During the daytime these leeches usually rest partially coiled up, as shown in the lower figure, and firmly attached by their hinder sucker to some rock; but their muscular strength is so great that they are able to maintain themselves extended in an almost horizontal direction, as represented in the upper figure of the illustration. They feed upon skates and other fish.

THE GEPHYREAN WORMS.—Class **Gephyrea.**

Gephyreans are marine, cylindrical, worm-like animals, presenting no distinct external segmentation of the body, and possessing nothing of the nature of limbs or gills. The skin is horny, though not calcareous, and often provided with tubercles, hooks, or bristles. The anterior end of the body is furnished with a retractile and sometimes highly-flexible proboscis, at the end or at the base of which the mouth is situated; the alimentary canal either traverses the body from end to end, as in *Bonellia* and *Echiurus*, or is coiled round a special spindle muscle, and returns upon its course to open in the front half of the body, as in *Sipunculus*, *Phascolosoma*, and *Phymosoma*. In the last-named genus the head is furnished with a circle or half-circle of tentacles. The muscular, vascular, and nervous systems are well-developed; the latter consisting of a cerebral ganglion, an œso-



GEPHYREAN WORMS.
A, *Bonellia*; *B*, *Phascolosoma*; *C*, *Priapulus*. (Nat. size.)

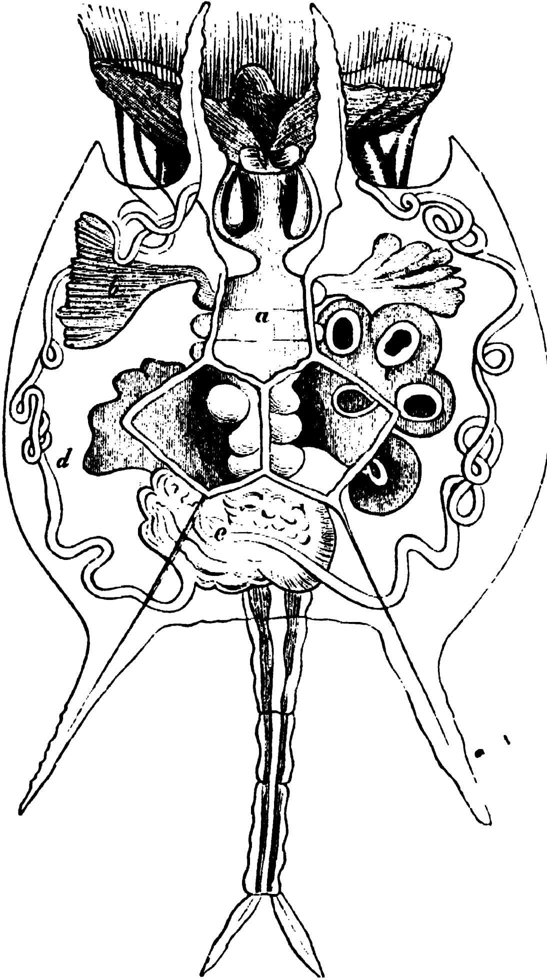
phageal collar, and a ventral chord, while the most important part of the vascular system is a dorsal vessel which lies above the alimentary canal. This class contains two orders, named the Achæta and Chætifera. In the former the mouth is placed at the apex of the proboscis, which is retracted by a special muscle as in the Nemertine worms, and the alimentary canal opens posteriorly in the front half of the body. Moreover, as the name of the order indicates, the integument is without bristles. In the illustration on p. 444, *B* represents *Phascolosoma*, one of the genera of the order. Here the narrowed part of the body is the extended proboscis, which is furnished at the tip with a cluster of tentacles. A second family of this order is the *Priapulidæ*, containing the genus *Priapulus*, of which a representation is given in *C* of the figure. In this form the body is short, stout, cylindrical, and furnished at the tail-end with a tuft of oval papillæ. The proboscis, which in the figure is represented as protruded, is short, stumpy, and covered with toothed ridges. The animal is found in deep water in the seas of Northern Europe, living in burrows on the sandy bottom.

The Chætifera, which in some respects approach the Annelids, differ from the Achæta in having the mouth situated at the base of the proboscis, and the vent at the hinder end of the body, as also possessing a pair of large hooks upon the front half of the lower surface. The best known is the genus *Bonellia*, represented at *A* in the illustration on p. 444. The proboscis is of great size, being often many times the length of the body, and is forked at the end. The males differ from the females, being minute,—not more than about one-sixth of an an inch long,—covered with cilia, and living within the kidneys of the females.

THE WHEEL-ANIMALCULES,—Class **Rotifera.**

The Rotifera, or wheel-animalcules, are small aquatic animals, varying from an eighth to the five-hundredth part of an inch in length, and derive their name from the circumstance that the circlets of hairs situated on the head give rise, when waving in the water, to the appearance of revolving wheels. The head end of the body is usually broader than the opposite extremity, and terminates in the wheel, or trochal disc, the edges of which are variously lobed, and clothed with the vibratile cilia, or threads. The body, which is indistinctly segmented, is either naked or enclosed in a hard transparent case, or *lorica*, open at both ends, which may be variously sculptured, and armed in front and behind with spiny processes, as shown in the annexed engraving. The posterior end of the body, termed the foot, ends usually in a pair of movable processes, by means of which the rotifers anchor themselves to foreign bodies of various kinds. The mouth, situated in the middle or at the side of the wheel-disc, is a funnel-shaped cavity, leading into a muscular gullet (*a*), provided with a peculiar armature of teeth, which serve to masticate particles of food that are swept into the mouth by the movements of the cilia on the wheel-disc. The nervous system consists of a single large ganglion, situated on one side beneath the disc, and sending forth nerves to the surrounding parts, and sometimes being furnished with one or more eye-spots. In all cases the males are smaller than the females, and further differ in having the alimentary canal aborted and reduced to a solid chord. Wheel-

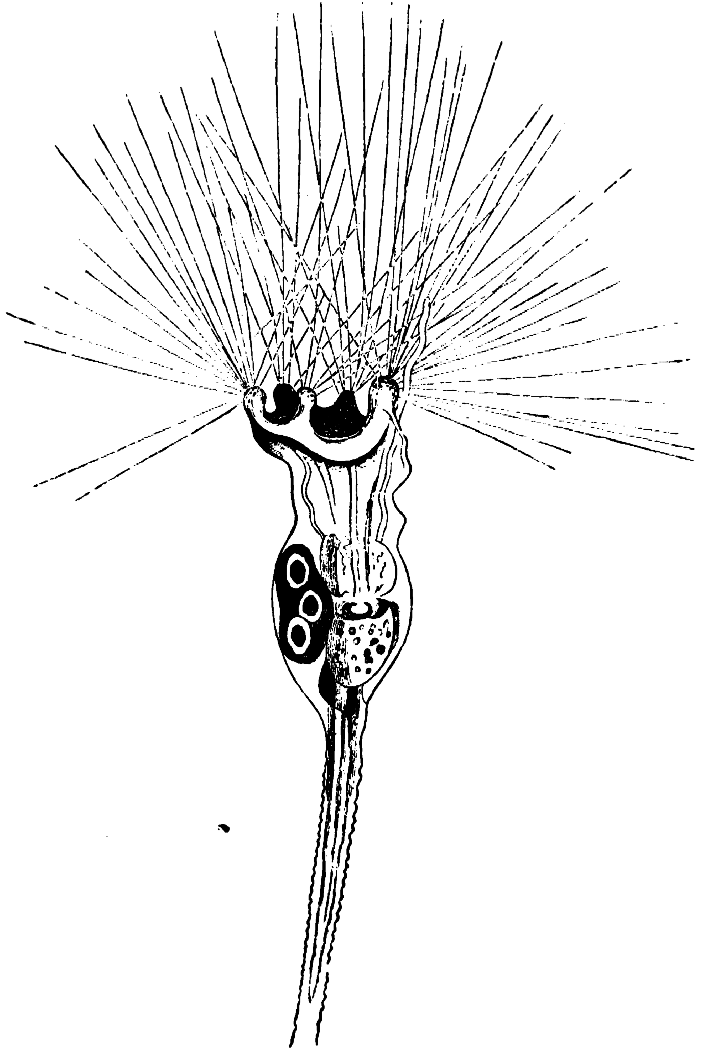
animalcules are divisible into four orders. Of these, the Ploima may be considered the typical order of the class, on account of the numbers of genera, the abundance of species, and the restless energy, perfection of structure, and superior intelligence of its members. Locomotion is effected by means of swimming with the ciliary wreath. The order is divided into two sections, the Loricata, which, as in *Noteus*, represented in the annexed illustration, are protected by an enclosing shell, and the Illoricata, which, as exemplified by *Notommata*, have the integument flexible, and the body not protected in a shelly case. The habits of the group show considerable variation. Many species may be found swimming freely or attached to water-weeds in almost any pond, stream, or stagnant ditch; and others, like *Brachionus*, one of the Loricata, may be seen riding in clusters on the backs and sides of crustaceans. Amongst the Illoricata, *Balatro calvus* — remarkable for having no disc—infests small water-worms, to which it clings by its enlarged foot-processes; and *Drilophagus bucephalus* is parasitic upon a water-worm (*Lumbriculus*), to which it clings, feeding by means of its modified jaws. Other species again form internal parasites, the genus *Albertia* being found in the interior of earth-worms, slugs, and annelids of the genus *Nais*; while *Notommata* may be seen swimming freely within the spheres of the beautiful *Volvox*.



FOUR-HORNED ROTIFER, *Noteus quadricornus* (enlarged 300 times).

The members of the order Bdelloidea swim by means of their ciliary wreath, and creep about like a leech. The foot is telescopically retractile, and ends almost invariably in three toes or claspers. In this group also the mode of life is varied. Most species are free-living, but others attach themselves to various entomostracous crustaceans, and *Callidina parasitica* is always found clinging to the appendages of the fresh-water shrimp and the aquatic wood-louse. A special interest attaches to this group on account of their vitality. If specimens be enclosed in a cell containing a little sand or moss, the contents may be dried over sulphuric acid or heated up to 200° F., or left to the neglected dust of years, and some of the little creatures will revive if a drop or two of fresh water be added to the sand.

The order Rhizota takes its name from its members being fixed when adult, and usually inhabiting a gelatinous tube. The foot is not retractile and ends in an adhesive disc or cup. In the flower-animalcules (*Floscularia*), which may be found everywhere in fresh water adhering to weeds, the edges of the wheel-disc are produced into distinct bristle-bearing lobes; but in the allied *Melicerta* there is no such production of the disc.


FLOWER-ANIMALCULE (magnified 200 times).

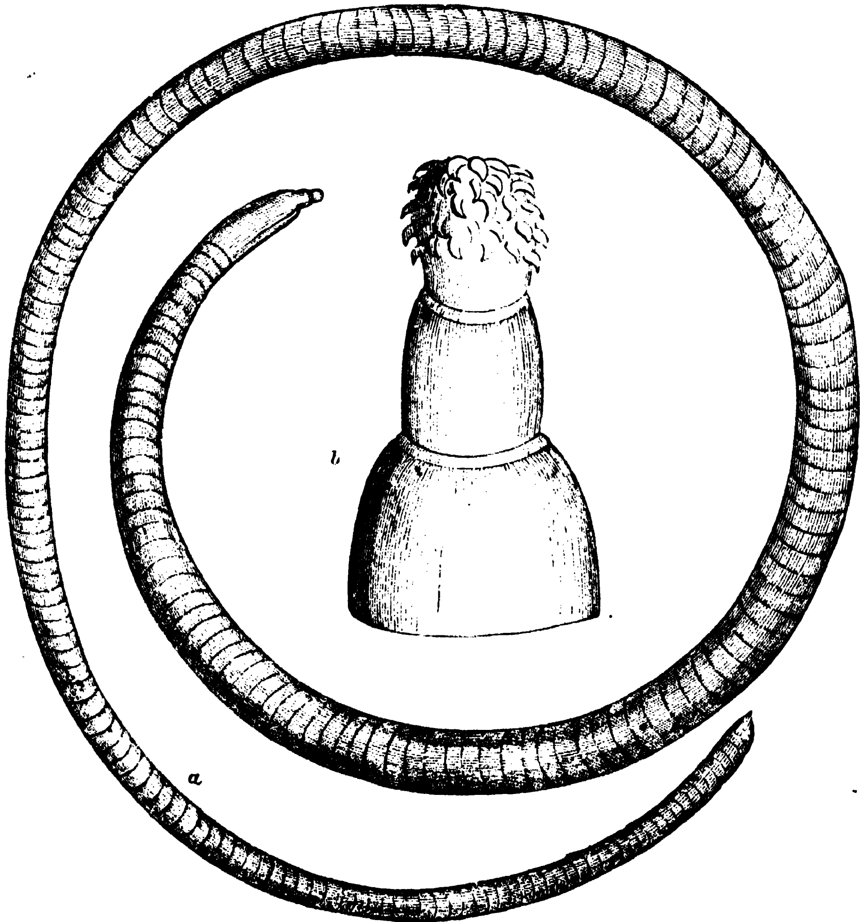
The last order, Scirtopoda, comprises only the two genera *Pedalion* and *Hexarthra*, each of which is represented by a single species. The two resemble each other and differ from all other rotifers in possessing three pairs of limbs, ending in a fan-shaped tuft of setæ. The body is conical with a broad square-cut head, furnished with two wreaths of cilia and a pair of conspicuous eyes. In *Hexarthra*, which bears a strong superficial resemblance to the *Nauplius* larva of some crustaceans, the three pairs of limbs spring from the ventral surface, the first pair being considerably the largest and the third the shortest; but in *Pedalion* they are arranged round the body in pairs, one limb projecting from the middle of the back, another from the ventral middle line and two from each side, the ventral limb being the largest of the six. By means of these appendages the creatures are able to project themselves through the water in a series of jerks. *Pedalion* has been discovered in various parts of England, and *Hexarthra* in brackish water in Egypt. The male of *Pedalion* is a veritable dwarf as compared with the female, the body and limbs being greatly reduced in size, and the latter merely represented by three stumps, each of which terminates in a pair of long bristles.

The Thread-Worms, or Round-Worms,—Class **Nematohelminthes.**

These worms are characterised by having a thread-like body, covered with tough, elastic integument, but usually showing no distinct traces of being divided into segments like those of leeches and earth-worms, and possessing no trace of limbs. The sexes are generally distinct. The group is divided into the three orders Acanthocephali, Nematoidea, and Chætognatha.

Spiny-Headed Thread-Worms,—Order Acanthocephali.

In this order is contained the single genus *Echinorhynchus*, which is appropriately named for animals possessing a protrusible proboscis, armed with several rows of backwardly-directed spines. The chief character in which this order



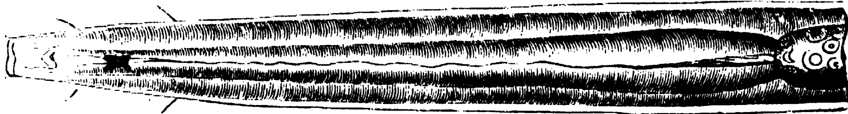
SPINY-HEADED THREAD-WORM. *a*, Nat. size; *b*, Head enlarged.

differs from the next is the lack of any special alimentary canal and digestive apparatus. In the adult stage the species of *Echinorhynchus* are found in the intestines of vertebrates; the large species figured above (*E. gigas*) infesting the pig. But in order to reach its final residence in this host, it has to spend its early

days in the grub or maggot of the cockchafer and allied beetles. These latter are rooted up and devoured by pigs, which thus unconsciously swallow the worm. Similarly, *E. proteus* of various fish lives in an immature state in the intestine of the water-shrimp, which swallowed it while still in the egg; and *E. moniliferus*, which occurs adult in such rodents as hamsters and voles, lives during the larval state in beetles. Another species, *E. polymorphus*, has to be transplanted from the body of the water-shrimp into that of a duck to reach maturity.

Typical Thread-Worms,—Order Nematoidea.

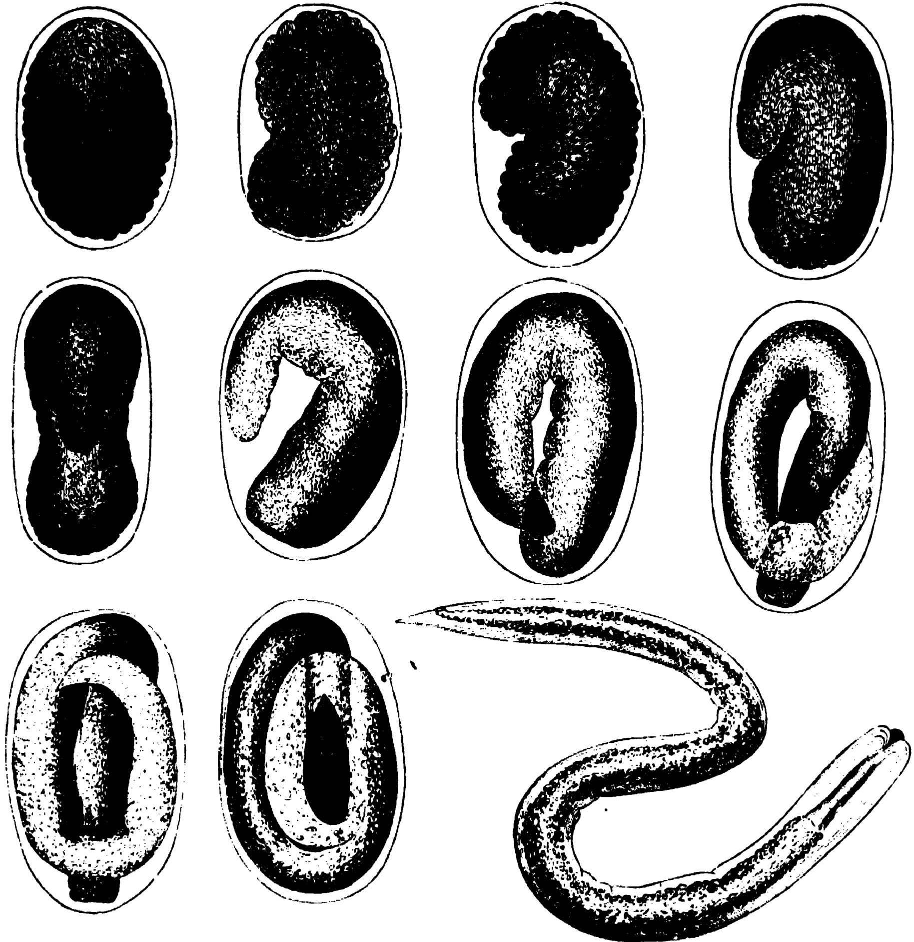
The illustration showing the growth and structure of one of the thread-worms (*Nematoxys*), an internal parasite of the frog, is intended to show the mode of development typical of the whole group. The egg is elliptical, and contains a mass of granular protoplasm, the external wall of which soon becomes marked out into a layer of large cells. Meanwhile, there appears at the side a distinct notch or nick, which, shallow at first, gradually deepens, until, as shown in the figures, it represents the space enclosed between the head- and tail-ends of the bent-up embryo, which may be recognised respectively by their blunt and pointed



FRONT END OF THREAD-WORM, *Enoplus* (much enlarged).

extremities. The external layer of cells becomes transformed into the cuticle, and the mouth appears as a depression at the end of the blunt head. When the muscular system and alimentary canal are developed, the embryo hatches in the form shown in the bottom right-hand figure. Most of the species lead a parasitic life, chiefly in animals; many, however, are free-living forms, occurring in damp earth, fresh water, and the sea. A genus, with marine habits, has received the name of *Enoplus*, and includes small, slim, transparent creatures, some of which are provided at the front end with isolated bristles (as shown in the illustration above), while many are furnished with a peculiar spinning-gland, opening beneath the tail. According to Schneider, "as soon as the animal has fixed its tail to something it moves on, and draws after it the secretion in a transparent thread, which is often several lines long. One end of this thread sticks fast, and by the other the animal floats freely in the water." The young are found in shallow water, and may be seen crawling on the surface of seaweeds; but the mature animals occur at depths of from two to three fathoms. As another example of non-parasitic species, we may take the common vinegar-eel (*Anguillula*), the magnified figure of which shows that the body is bluntly rounded at the head-end, and narrowed and pointed at the tail. The greater part of the body-cavity is occupied by the alimentary canal, which traverses it almost from end to end. The oval particles contained in two tubes, which unite and open by a common orifice, are the eggs. This worm appears to live both in vinegar and paste, although it does not seem to derive its nourishment directly from either of these substances, but rather from

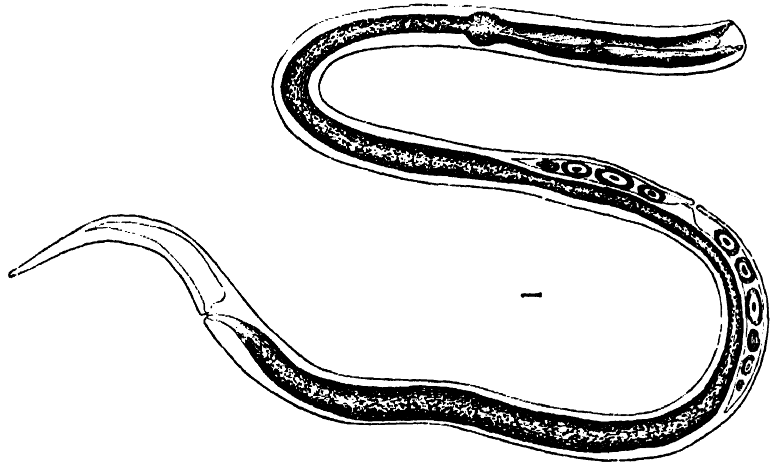
the microscopic fungi growing in them. These worms now appear much rarer in vinegar than former observers have represented; and it is suggested that the reason of this may be that vinegar is no longer made from wine or beer; since, in the vinegar obtained from the two latter, there probably remained much sugar and albumen, which form a favourable basis for the growth of fungi, and therefore for the eels. The maturing and propagation of these animals cannot take place in pure vinegar, but only amongst fungi, where a nitrogenous diet is offered.



DEVELOPMENT OF THREAD-WORM, *Nematoxys* (400 times enlarged).

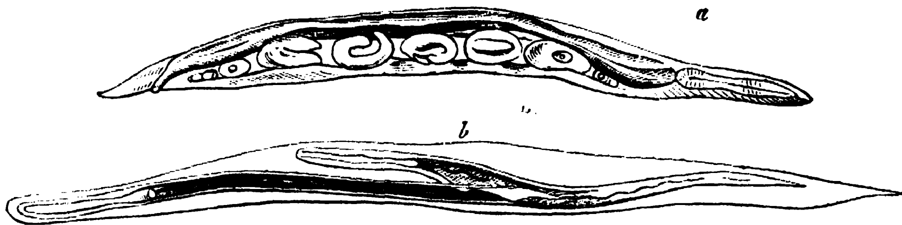
Vinegar now never contains adult eels, but, at most, larvæ and the innumerable little creatures supposed to be seen upon shaking a bottle of vinegar are, for the most part, nothing but the skin-skeletons of these animals. Nearly allied is the wheat-eel (*Tylenchus tritici*), which is the cause of a serious disease to the cereal from which it derives its name. In the ears of wheat affected by this worm the grains are misshapen, blackish, and consist of a thick hard scale enclosing a white powdery substance, composed of the larval forms of the worm. If grain in this state is sown in moist ground, it merely rots; but the larvæ awake to activity, and scatter over the ground in search of another growing blade of corn.

If they fall in with one, they start to creep up it, and mounting ever higher and higher, as the corn grows, ultimately succeed in reaching the summit. They then attack the soft grain, bore into it, and form gall-like swellings, in the middle of each of which there is a larval worm. Here the worms quickly develop to normal perfection, and after the females have laid a large quantity of eggs, both they and the males die. Subsequently the eggs hatch, and the larvæ, which constitute the powdery substance referred to above, make their appearance. Somewhat similar diseases are produced in other grains by members of the same family; and the turnip-eel (*Heterodera*) is very destructive to root-crops.



VINEGAR-EEL (much enlarged).

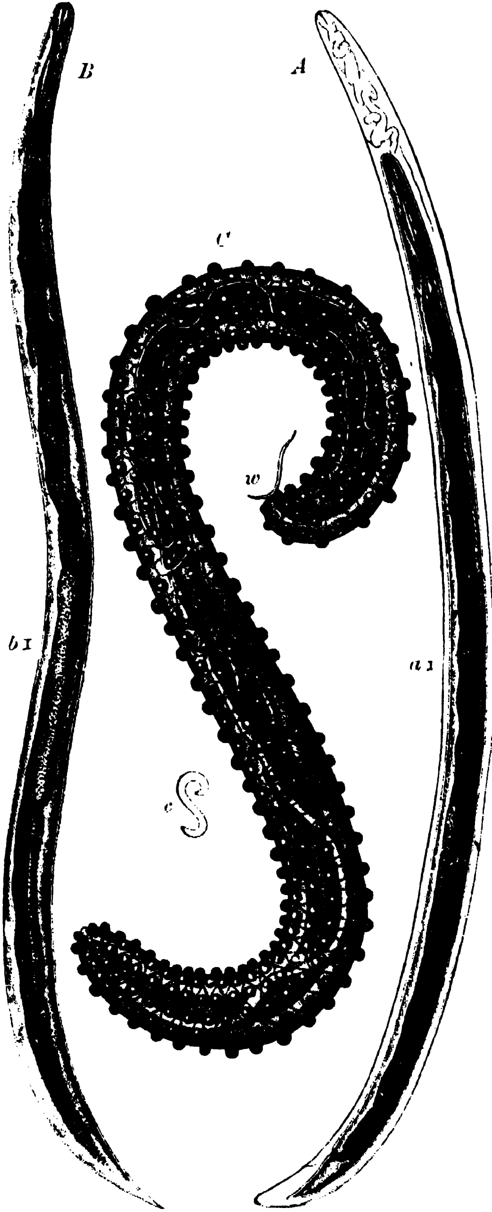
Of the parasitic forms, the genus *Rhabdonema* has a remarkable course of development, one species (*R. nigrovenosum*), which is about three-quarters of an inch in length, living, sometimes in great numbers, in the lungs of frogs. This species is hermaphroditic, and produces innumerable young ones, which bore their way from the lungs into the alimentary canal of their host, whence they are expelled with the remains of their food. They then develop in a few days into free-living, separately-sexed individuals, bearing a close resemblance to another free-living worm (*Rhabditis*). These individuals breed; the females bear one or two young apiece, and these, after devouring their mother's vitals, and making their escape by bursting through the skin of her body, pass through a frog's mouth into its lungs, and become the hermaphrodite adult. Another species (*R. strongyloides*) is of interest, inasmuch as it is parasitic in man in warm climates.



a, FEMALE OF *Rhabditis*—FORM OF *Rhabdonema nigrovenosum*; *b*, BROOD-POUCH. (Enlarged.)

Two more remarkable Nematoids may be mentioned, both of which infest insects. The first of these, *Atractonema gibbosum*, is found in numbers in the body-cavity of the larval and adult stages of the midge; the completely-formed

worm reaching a length of nearly one quarter of an inch. Its shape is unusual, on account of the presence of a hump projecting like an excrescence from the surface of the abdomen, some distance from the tail-end. When fully formed, this excrescence amounts in size to half the length of the entire worm, and contains the young, which, after making their escape, undergo a short development in the body-cavity of the midge, then reach the outside, where they are transformed into mature males and females. After the pairing of the sexes, the males perish, but the females again enter the larva and start another cycle of metamorphosis. The second kind (*Sphærularia bombi*), which infests humble-bees, closely resembles the first in development; but the excrescence, or brood-pouch, of the mother-worm is changed into a tube, and ultimately reaches a size from fifteen to twenty thousand times as great as the parent, which dwindles in size in proportion as the sac grows. The life-history of this worm is shown in the illustration, where *A* is the free-living male, *B* represents the free-living female, and *C* is the parasitic female (*w*), with her brood-pouch.

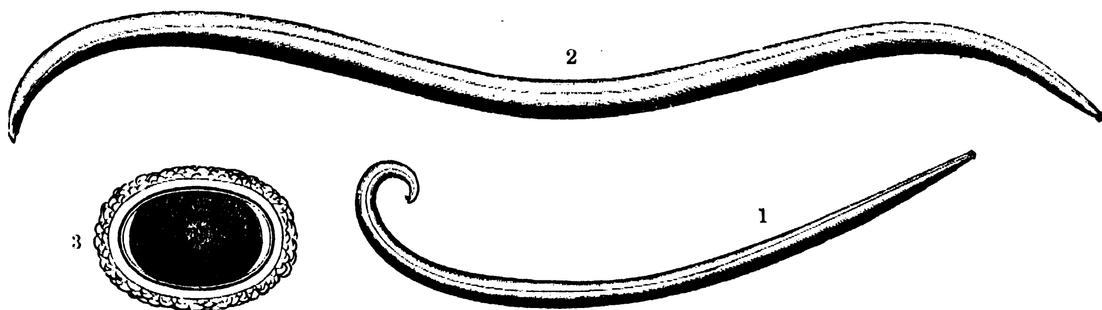


HUMBLE-BEE THREAD-WORM.

A, Male enlarged: *a*, nat. size.
B, Female enlarged; *b*, nat. size.
C, Brood-pouch of female (*w*); nat. size.

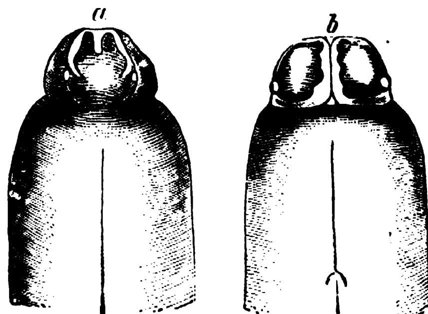
Of the thread-worms infesting the human body, one of the commonest is *Ascaris lumbricoides*, which is found in numbers varying from one or two only to over two thousand. These worms usually infest the small intestine, but sometimes enter the stomach, or even penetrate into the liver. Large examples reach a length of 6 inches or more, and the females produce about sixty millions of eggs annually. These are naturally dispersed abroad everywhere, and as the young worm retains its power of growth in spite of frost, drought, and, in fact, the most unfavourable circumstances imaginable, and is, moreover, far too small to be noticed, we need not feel surprised at the prevalence of the pest. The form and some of the structural characters of this worm are shown in the two illustrations on p. 453. In the uppermost, 1 is the male, and 2 the female, of the natural size, 3 being the egg, enormously

enlarged; the lower illustration depicting the upper (*a*) and the lower (*b*) side of the head, with the prominent lips. Other mammals, besides man, are the hosts of different species of *Ascaris*. For instance, *A. mystax* is found in dogs and cats, and sometimes even in man; while *A. lumbricoides* also occurs in swine. A large species, *A. megalocephalus*, the female of which reaches a length of over a foot, lives in horses and cows. A second common parasite of mankind is *Oxyuris vermicularis*, a small, white, sharp-tailed worm, which measures about one-quarter of



HUMAN ROUND WORM (*Ascaris lumbricoides*).
1, Male; 2, Female. (Nat. size.) 3, Eggs (enlarged).

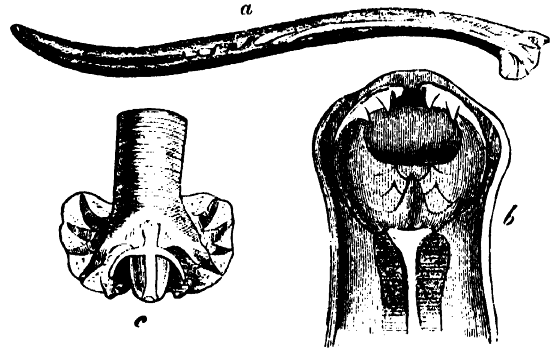
an inch in length. It occurs abundantly in children and growing people. As, in the case of *Ascaris*, it seems that before development can take place, the egg must pass out of the host, and again make its entry into the alimentary canal through the mouth. These worms are so small and light that, when dried, every current of air will scatter them, and they may make their way into the alimentary canal of their host in connection with almost any kind of food. To the family *Strongylidæ* belongs a dangerous parasite, *Dochmius duodenalis*, occurring in the intestine. It is about half an inch in length. A peculiarity of this species and others of the genus is that the posterior end of the male is furnished with a curious bowl- or fan-shaped ruff, which is often supported by thick ribs (*a* and *c* of the figure on p. 454). The gullet, at least in individuals that are still growing, is furnished with strong teeth (*b*). When this worm appears in masses, it produces the disease known as Egyptian cholera.



HEAD OF HUMAN ROUND WORM (enlarged).

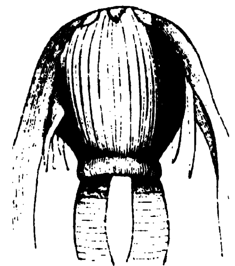
The accompanying illustration is an enlarged view of the head of *Cucullanus elegans*, a parasite in fresh-water fishes like the perch, and having for its intermediate host the Crustacean *Cyclops*. The worm is about half an inch long, and the aperture of its mouth forms an elliptical case with thick brown walls. The female bears living young, which creep forth from their egg-cases while still within their mother's body, where they may be counted in thousands. Protected by a tough skin, the worms, which have reached the outside world, frequently live for several weeks in the water on the look out for a favourable host. Having come across, and made their way into a *Cyclops*, they undergo various changes, but only

reach in this host a length of about one-twelfth of an inch, their complete development only taking place after the swallowing of the infested *Cyclops* by a fish. Another member of the same family is the *Syngamus trachealis*, which owes its double name to the fact that the males and females are found in pairs in the windpipes of various birds. They sometimes occur in such numbers that the inflammation set up by their blood-sucking suffocates their host. The eggs appear to be brought up into the bird's mouth by crowing, or by the choking cough that the presence of their parent causes. They are then swallowed, and pass out through the alimentary canal. As soon as they have obtained sufficient dampness and warmth, they develop in about a week's time into small thread-shaped embryos, with a blunt head and pointed tail. These obtain an entrance into another, or the same bird's mouth with the food, and thence pass into the windpipe.



Dochmius duodenalis. a, Entire; b, Head (enlarged); c, Tail (enlarged).

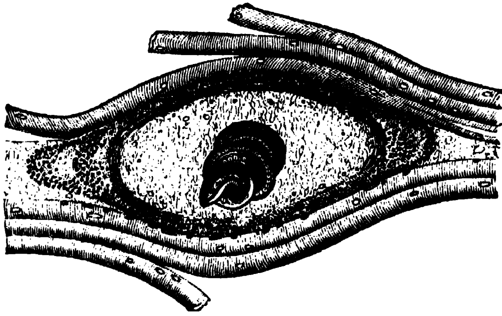
Perhaps the most dangerous of all human internal parasite worms is *Trichina spiralis*. In the mature stage these creatures live in the intestines of mammals and birds, where they propagate and gradually perish. The females are about one-eighth of an inch long, and twice the size of the males. In both sexes the mouth lies at the front end of the body, which is its narrowest part; the tail is stumpy, and in the male provided with a pair of short processes. The number of progeny produced by one female may amount to some thousands, and as soon as these are born they make their way into the blood-vessels of their host's intestine, where they are carried by the circulation to some more distant part of the body, and ultimately come to a stop in one of the muscles. Here by feeding they grow in a few weeks to four times their original size, and form between the muscular fibres a great cyst or capsule, in the centre of which the worm lies coiled up in a spiral. It has not been ascertained how long the creature can remain in this immature state, but



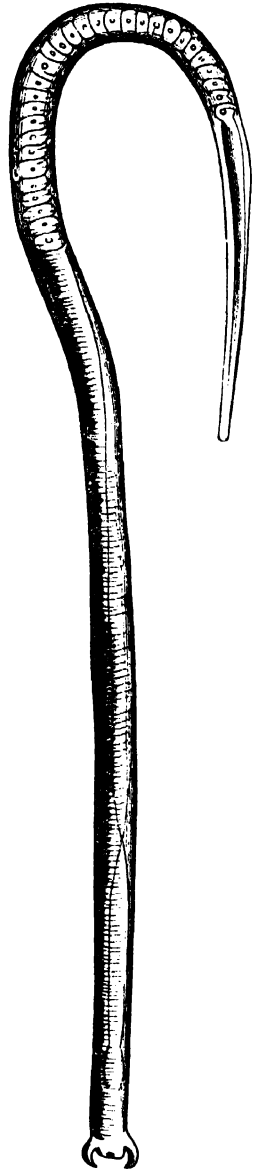
HEAD OF *Cucullanus elegans* (enlarged).

HUMAN THREAD-WORM, *Oxyuris vermicularis* (much enlarged).

certainly for years, and perhaps decades. It can, however, develop no further until introduced into the intestine of a suitable host. For instance, if the muscles of a pig be infested with trichinas, and eaten in an uncooked state by a human being, the immature worms are set free in the intestine of the new host, where they grow to maturity, and produce young. To the genus *Filaria* belong two other worms parasitic upon man, and the cause of sickness. One commonly known as the guinea-worm, and occurring in the tropical and subtropical countries of the Old World, lodges itself beneath the skin, producing abscesses. It may attain a length of several feet, and the operation of extracting it from the patient demands considerable skill and patience. The second species lives in the blood and lymphatic vessels, and is said to cause elephantiasis. The larvæ are sucked from human blood by mosquitoes. When the insects perish, the worms make their escape into water, where they attain maturity and produce their young, which are subsequently taken into the human body when the water is drunk.



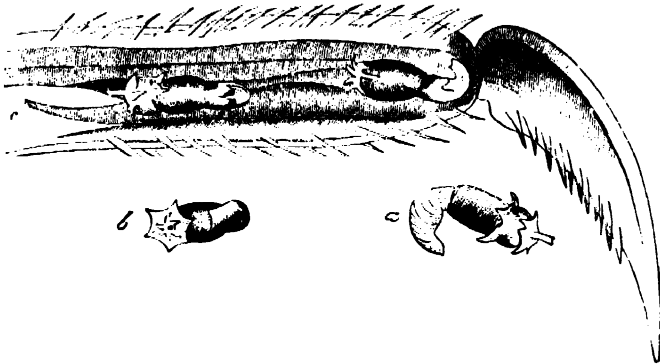
TRICHINOSIS WORM COILED UP IN HUMAN MUSCLE (enlarged).



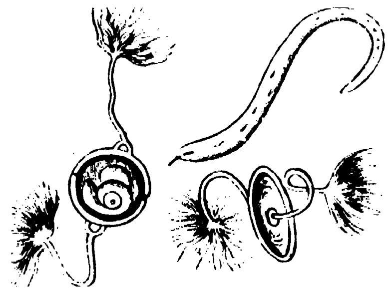
TRICHINOSIS WORM, *Trichina spiralis* (male enlarged).

The family of hair-worms, *Gordiidæ*, owe their English name to the resemblance that their long, black, slender, flexible body bears to a hair from a horse's mane or tail, and their scientific title, *Gordius*, to the peculiar habit the animals have of tangling and entwining themselves in a way that may be compared to a Gordian knot. The best-known species is *G. aquaticus*, the average length of which is about 4 inches, although specimens three times that length have been obtained. The width of a male is about one-thirtieth of an inch, the females being slightly wider. The prevailing colour is brown of various shades; the males, however, are always darker and more polished than the females, and are often of a deep shining black, while the females vary from light yellow to deep yellow-brown. Upon the middle of the abdomen, both in males and females, runs a long dark streak, visible even in the darkest males. Another mark by which the male may be recognised is the bifurcated tail end. Although living a free life in the adult condition, these worms spend the greater part of their lives, up to the last period, in certain insects. The young hair-worms, as they issue from the egg, are scarcely more than one twenty-fifth of an inch in length, and most

curiously shaped; the body being cylindrical, and consisting of a thick fore-part, and a thinner tail-like appendage. Out of the front end of the body a sort of head can be thrust, which is armed with two circles of small hooks, and tipped with a horny proboscis. With these instruments the creatures, in the first place, bore their way through the egg-shell, and, having made their escape, lie quietly at the bottom of the water without appearing to wander in search of a host. Insects, however, in the adult and larval stage abound in most fresh waters, and sooner or later the young worms come across them. They then seek out a soft spot, bore a hole by their apparatus of hooks, and by a series of contractions and extensions of the body force an entrance between the muscle-fibres of the limb, whence they spread into the body-cavity of their host. In the illustration, *a* and *b* show two views of the larva with its armature of hooks, and *c* represents two that have effected an entrance into the foot of the larva of a May-fly. They also infest in this way water-bugs and gnats. All these water-insects, however, are liable to be devoured by fresh-water fish, and by this means the young hair-worms are set free in the intestines of the fish, where they undergo their metamorphosis, and after five or six months pass into the water in the mature form. Nearly allied is the family *Mermithidæ*, containing the genus *Mermis*. Like the hair-worms, they occur both singly or coiled up and entwined with each other. The eggs are curiously constructed, having the form of lenticular capsules, with a pair of tassel-shaped appendages projecting from their flat surfaces. Eggs of *M. albicans* laid in the summer do not hatch until the spring. After remaining a short time in the earth, the young search for insects and larvæ, bore a way into their bodies, where they gradually grow to maturity, and ultimately pass out to lead a free life, when they pair and lay their eggs. They may be found in caterpillars, grasshoppers, and more rarely spiders.



LARVÆ OF *Gordius*—*a*, showing proboscis, and *b*, circlets of hooks on the head; *c*, two examples lodged in the foot of a larva of the May-fly.

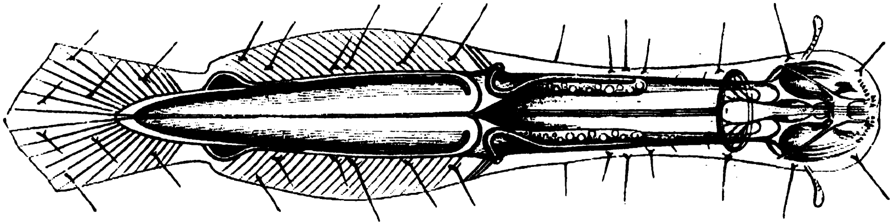


EGGS AND LARVA OF *Mermis* (enlarged).

ARROW-WORMS,—Order CHÆTOGNATHA.

The small group of worms included under this heading are of doubtful position. They are glass-like, transparent creatures living in the sea, near the surface of which they swim in numbers. They are most active and vigorous swimmers, as

might be expected from their slender build, and the presence of a large horizontal fin at the sides of the hinder half of the body, projecting beyond the tail. The shape of the body and the presence of the large tail-fin suggested the name *Sagitta*. The head is bluntly rounded and furnished with a pair of eyes, a pair of feelers,

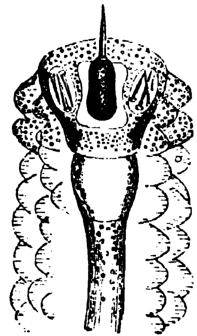


ARROW-WORM (25 times nat. size).

and an armature of close-set horny teeth, all of which must be of the greatest service to the animal in its roving, predaceous life.

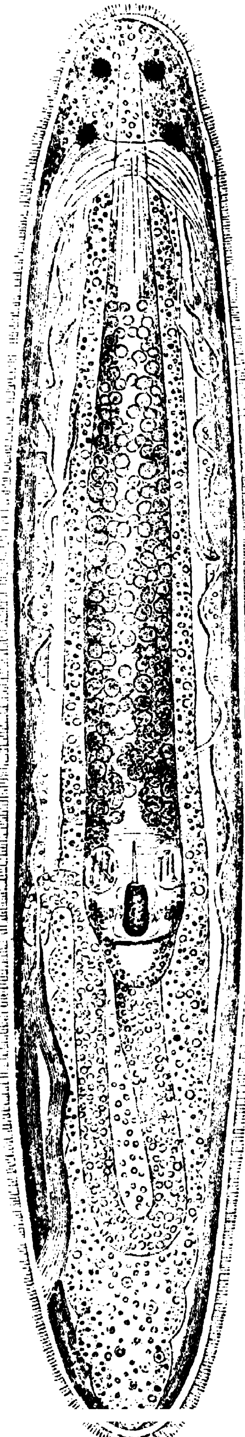
The Nemertine Worms,—Class **Nemertinea.**

All the members of this group are characterised by having the body elongate and flattened, at least on the abdominal side; at the front end there are frequently two clusters of eyes, and two apertures, one of which leads into the alimentary canal, and the other into a cavity containing a peculiar organ known as the proboscis. The latter, which is used as an instrument for prehension, can be thrust out with swiftness to a considerable distance, and in many species is armed in the middle with a sharp spike-like tooth and some smaller ones at the sides, which are brought by degrees into use as the large median one is worn away or fractured. This organ is shown protruded in a small marine species (*Tetrastemma obscurum*) in the illustration on this page, and retracted within the body in the full illustration of the animal on p. 458. The creature thrusts forth its proboscis with lightning speed at passing animals, such as crustaceans. The figure of *T. obscurum* illustrates other characters in the anatomy of these animals. The two swellings situated in the head end and united by a cross bridge constitute the brain or chief centre of the nervous system; running backwards from each to the hinder end of the body is a long nerve-chord, supplying the muscles and other organs of the body. The winding curled tubes, which also run the length of the body, are the so-called water-vessels. These worms, which have received their generic name from the presence of four eyes, are widely distributed, most of the species being minute, and commonly found among seaweed. The worms of this group that have hitherto been discussed have the proboscis armed with stylets, and are consequently called the Hoplophora, or armed nemertines. The second division, namely, the Anopla,—comprising those kinds which have no spines upon the proboscis,—contains some of the largest species of the class, *Meckelia somatotoma* reaching a length of



END OF PROBOSCIS OF *Tetrastemma* (enlarged).

from 3 to over 6 inches. It is a long, flat, whitish-coloured creature, occurring on muddy ground and between the branches of coral; and has received its name from the habit of breaking up into pieces at the least touch. The vitality of the severed pieces is so great that the head end has the power to re-form a new tail, and the tail end a new head, and the intermediate pieces a new head and tail. Another common kind is *Polia crucigera*, so-called because its greenish body is marked with five longitudinal white bands and transverse white stripes, forming together a series of crosses. These worms are long and slender, reaching a length of about 16 inches. The proboscis, moreover, when protruded, adds another 6 inches to their extent. They are found most abundantly in pieces of rock riddled with holes and galleries by boring sponges, and they also intertwine themselves amongst the prongs of branching-corals, as shown in the illustration.



FOUR-EYED NEMERTINE, *Tetrastemma obscurum* (enlarged).

Most marine nemertines prefer rather shallow water; but some occur at considerable depths; and a pelagic species from the Indian Ocean, originally described as a mollusc, under the name *Pterosoma planum*, is a transparent creature, whose internal organs, especially the chestnut-brown digestive apparatus, are visible through the colourless integument. The body diminishes from the front towards the hinder end, and at the sides is marked out by deep notches into a series of five lobes, of which the first pair are enormously large, and have the form of two semicircular wings. The use of these is doubtless to enable the creature to float or swim in the water. All the foregoing are free-living types, but we now come to forms (*Malacobdella*) not unfrequently found living parasitically under the gills of various marine molluscs. In these, the body is short and broad and capable of but little change in shape at its hinder end; it is furnished with a sucking apparatus, by means of which the animal adheres to its host. As stated above, almost all nemertines are of separate sexes; and in some marine species the development of the young is so remarkable that it is impossible to pass it by without notice. The young which issue from the egg are so unlike the parent, that no one would at first sight suppose them to belong to this group. The larva, as shown on p. 461, bears some resemblance to a helmet, and has been named *Pilidium*. This creature, which is covered with cilia, swims near the shore for some time, while the young nemertine is developed inside. As soon as this has acquired its cilia, and attained a certain stage of maturity, it breaks from the pilidium and starts an independent life.

The Flat-Worms,—Class **Platyhelminthes.**

The flat-worms are characterised by the absence of a distinct vascular system, and by the alimentary canal being either absent or with no posterior outlet. A nervous system is developed, consisting either of a network of nerves, or sometimes of a distinct brain and lateral chords. The excretory organs are composed of fine tubules opening to the exterior, and the body-cavity is reduced to a set of slits in the tissues. For the most part the sexes are united in one individual. Sometimes a sexual reproduction occurs, accompanied by an alteration of generations. There are three orders of flat-worms, namely, the tape-worms, the trematodes, and the turbellarians.

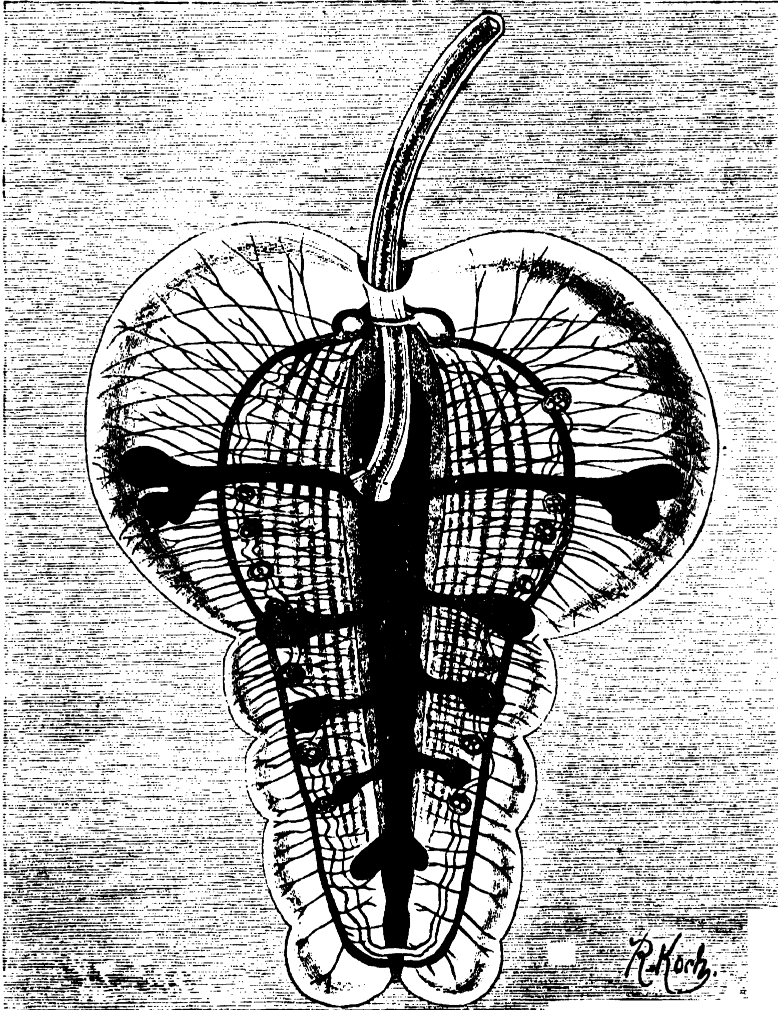


CROSS-BEARING NEMERTINE (*Polia crucigera*) ON A CORAL (nat. size).

Tape-Worms,—Order Cestoda.

The members of this extensive group are internal parasitical worms with the body divided into a number of segments. There is no trace of an alimentary canal, nutriment being obtained by the absorption of juices through the entire surface of the body. The head is furnished with suckers, or hooks, or both, by means of which the worm adheres to the walls of the intestine of the host it infests. The nervous system consists of a ganglion in the head, and a cord on each side. As a well-known example, we may take *Tænia saginata*, one of the human tape-worms; and since its structure and the phases through which it passes in the course of its development are thoroughly known, a detailed discussion of its characteristics will serve as an introduction to the study of the group. In its

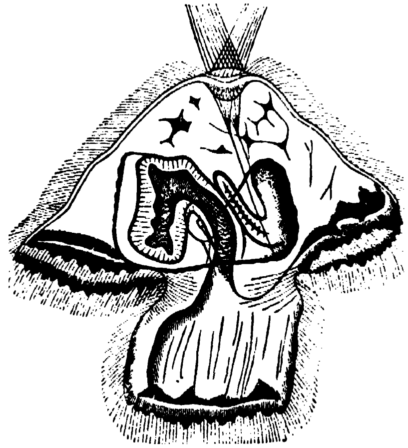
mature state this worm, which spends this stage of its existence in the human intestines, may reach a length of 5 or 6 yards. Its head is relatively minute, being only about equal to that of an average pin in size, and furnished with four suckers, by means of which the creature adheres firmly to the walls of the intestine. The head is followed by a narrow piece called the neck, which gradually passes posteriorly into the trunk. It is not jointed, but where it merges with the



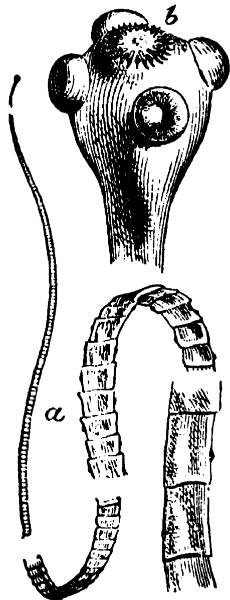
A NEMERTINE, *Pterosoma planum* (enlarged).

trunk it becomes marked by shallow grooves, growing deeper and deeper as they recede from the head, until ultimately they divide up the body into a chain of flattened, square or oblong segments, of which there may be many hundreds. Each segment is called a *proglottis*, the whole series being termed *proglottides*. The muscular system is fairly well developed, and consists of fibres running lengthwise throughout the segments and across from side to side, and of others passing from the upper to the lower walls. By means of these muscles the worm is able to shift at will its point of attachment to the gut, and to lengthen or

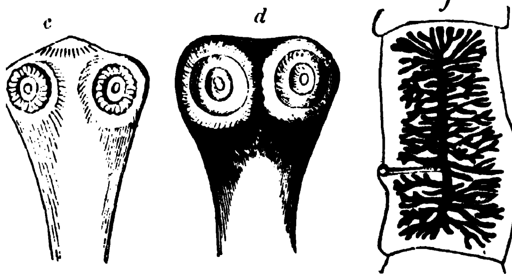
shorten its body to a very considerable extent. The chief centre of the nervous system lies in the head, and from this portion, which may be called the brain, nerves pass forwards to supply the suckers, while a single stout cord runs backwards on each side to the end of the body, lying close to the edge of the segments. As already pointed out, there is no trace of a mouth nor intestinal canal, although there is an excretory organ, consisting of a ring-shaped vessel in the head, from which four tubes, corresponding in position with the sucker, are prolonged backwards. Two of these soon vanish, but the others lying near the edges of the segments, close to the inner side of the nerve-chords and the longitudinal muscular band, extend to the hinder end of the body, where they unite and communicate with the exterior by a common aperture. At the hinder end of each of the segments these two ducts are united by a third, which runs across from side to side. In addition to these structures, each fully-grown segment contains a complete set of organs for the formation and fertilisation of eggs, of which an immense number are developed. The mature segments begin at a distance of about a foot from the head, and those at the hinder end of the body are the first to become distended with eggs ready to hatch. The eggs, however, are not laid within the human body, but the ripe segments break off one by one, beginning with the last, and pass out of the intestine. The rupture is effected by the contraction of the muscular fibres, which acts upon the transverse vessel of the excretory system of the segment in front, in such a way that a fresh terminal pore is formed. The ripe *proglottis*, or segment ready for separation, is little more than a sac that is crammed with minute spherical eggs, set free by the bursting of its walls. In this way the eggs, which, on account of their thick protecting shell, are able to withstand the most unfavourable conditions, are disseminated abroad; and, owing to their vast



PILIDIUM LARVA, WITH NEMERTINE WORM DEVELOPING INSIDE.



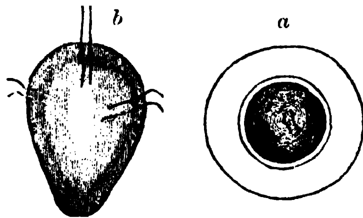




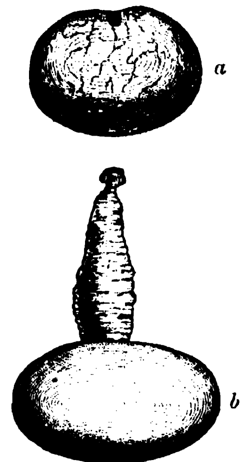
HUMAN TAPE-WORMS.

Tænia solium (nat. size); *b, c, d,* Head enlarged; *e,* Segments *f,* Segment of *Tænia saginata* (enlarged).

numbers and minute size, some ultimately succeed in making their way in connection with either food or water into the stomach of an ox. Here the egg-shell is dissolved by the action of the digestive fluids, and a small embryo, the *proscolex*, is set free. This embryo is a small round creature furnished with six hooks, arranged in three pairs. Upon this proscolex the gastric and intestinal juices have no effect; but instead of undergoing further development in the alimentary canal of the ox, it bores by means of its hooks into the blood-vessels of its host, and is thus carried by the circulation into the muscles, liver, lungs, brain, or other suitable resting place, where it starts its growth. Here it elongates, and becomes larger, while the hooks drop off and the central portion liquefies, so that a bladder of fluid is formed. When these bladders—which are oval and about a quarter of an inch in length—are found lying side by side between the muscular fibres of beef, the meat is spoken of as measly. The next step is the formation of the head, which takes place in the following way. At one spot on the side of the bladder an infolding of the outer skin takes place, and this elongates until converted into a hollow sac projecting into the cavity of the bladder. At four equidistant points near the bottom of the pushed-in sac the suckers of the head appear. The head therefore is developed outside-in, but subsequently it is pushed out, and the embryo, which in this stage is termed *Cysticercus bovis*, consists of a head, a neck, and a bladder. Beyond this stage the tape-worm cannot go so long as it remains in the body of the ox. If, however, the latter be killed for food, and its affected flesh eaten in an uncooked state, the bladder and neck of the *Cysticercus* are dissolved by the digestive fluids, while the head, which is often spoken of as the *scolex*, fixes itself to the walls of the intestine, its neck gradually elongates, and the body grows and becomes divided into segments, or *proglottides*. Another common tape-worm in Europe is *T. solium*, which is scarcely so long as *T. saginata*, and may be distinguished by the presence of a circlet of hooks on the head in front of the suckers, as well as by the smaller number of egg-sacs in the ripe segments. It has long been well established that human beings share with pigs in the breeding of this tape-worm, the bladder worm stage (*cellulosæ*) being found in one of these quadrupeds, and the cycle of development similar in all respects to that of *T. saginata*. In addition to being found in swine, the bladder-worm stage of *T. solium* also occurs in a few other animals, such as monkeys and dogs; and even in man, if through any accident an egg has been swallowed, the *Cysticercus* duly makes its appearance in the muscles, heart, brain, or eye, and may thus be the cause of very serious consequences. Another tape-worm (*T. cucumerina*), sometimes found in man, frequently lives in

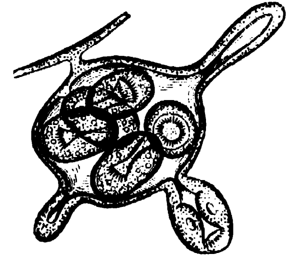


EGG (*a*) AND SIX-HOOKED EMBRYO (*b*) OR *Proscolex* OF TAPE-WORM.

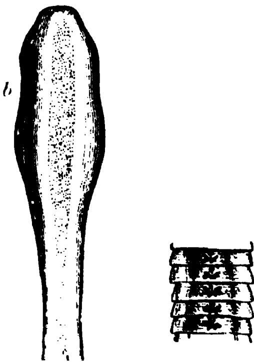


BLADDER-WORM STAGE (*Cysticercus*) OF TAPE-WORM.
a, With head beginning to turn; *b*, With head protruded.

abundance in dogs and cats. Many other tape-worms live in these mammals, one of the commonest infesting the former being *T. serrata*, distinguished by a double row of hooks on the head. In the bladder-worm stage this species lives in rabbits and hares. The commonest form in cats is *T. crassicollis*, which has a large head and a short thick neck, its bladder-worm stage being passed in mice. Perhaps, however, the most important tape-worm of the dog is *T. cœnurus*, interesting on account of the remarkable features it presents in its condition as a bladder-worm, and the serious disease, known as the staggers, which its presence in the brain brings upon sheep. Another pest of much the same nature is the bladder-worm known as *Echinococcus*. The mature worm living in the dog is a small tape-worm, scarcely more than a sixth of an inch in length, and differs from the species hitherto discussed, in that it consists merely of a head, neck, and three distinct segments, of which the third or last becomes ripe and then equals the rest of the worm in length. The head, like that of *T. solium*, is furnished with suckers and hooks, and the embryo which hatches from the egg is armed, like the rest, with six hooks. The bladder-worm stage occurs in both men and pigs, and each bladder becomes the brooding-place of a large number of others. Upon the surface of the bladder several ingrowths are developed, and each of these gives rise to a single head. As many as twelve, fifteen, or twenty may be formed. The bladder, however, sometimes becomes more complicated by the formation, either outwardly or inwardly, of secondary head-producing vesicles, so that the original cyst is enveloped by others which have arisen as its buds. To complete the register of the tape-worms, whose life-histories are bound up with our own existence, the genus *Bothriocephalus* must be mentioned. The commonest species (*B. latus*) is the largest of human tape-worms, and may attain a length of nearly 10 yards, and be furnished with from three to four thousand segments. It may be at once distinguished from the species of *Tænia* by the shape of its head, which is long, flattened, and furnished with a deep cleft or slit on each side. The intermediate hosts of this worm are fresh-water fish. Belonging to the same class as the preceding is the strap-worm (*Ligula simplicissima*), which reaches maturity in the intestine of various water-fowl, but is found in the bladder-worm stage in the body-cavity of whiting, which swallow the eggs expelled from birds. A peculiarity of this worm is, that the segmentation of the body into proglottides does not take place.



Tænia echinococcus (enlarged).



BROAD TAPE-WORM (*Bothriocephalus*). *a*, Head nat. size; *b*, Head enlarged; *c*, Segments.

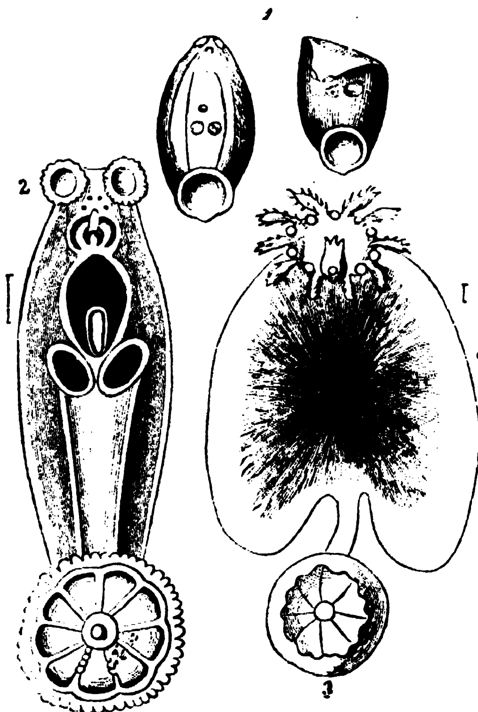
TREMATODE WORMS,—Order **Trematoda**.

Some of the less highly organised members of the preceding group, namely, those which are not segmented, are nearly related to the present section of

parasitic worms. In this class the body is unsegmented, usually leaf-like in form, smooth-skinned, and provided with suctorial discs in the middle or at its hinder end. There is a distinct digestive canal, usually forked, but provided with only one aperture, namely, the mouth. The excretory organs open by one or two pores at the hinder end of the body, and, as in the tape-worms, the male and female generative organs coexist in one individual. Although all are parasitic, the higher members are external parasites, and develop without migration; whereas the lower ones make a complicated migration, with intermediate stages of development, spending their youth in one host, and their maturity in a second.

MANY-SUCKERED GROUP,—Suborder **Polystomeæ.**

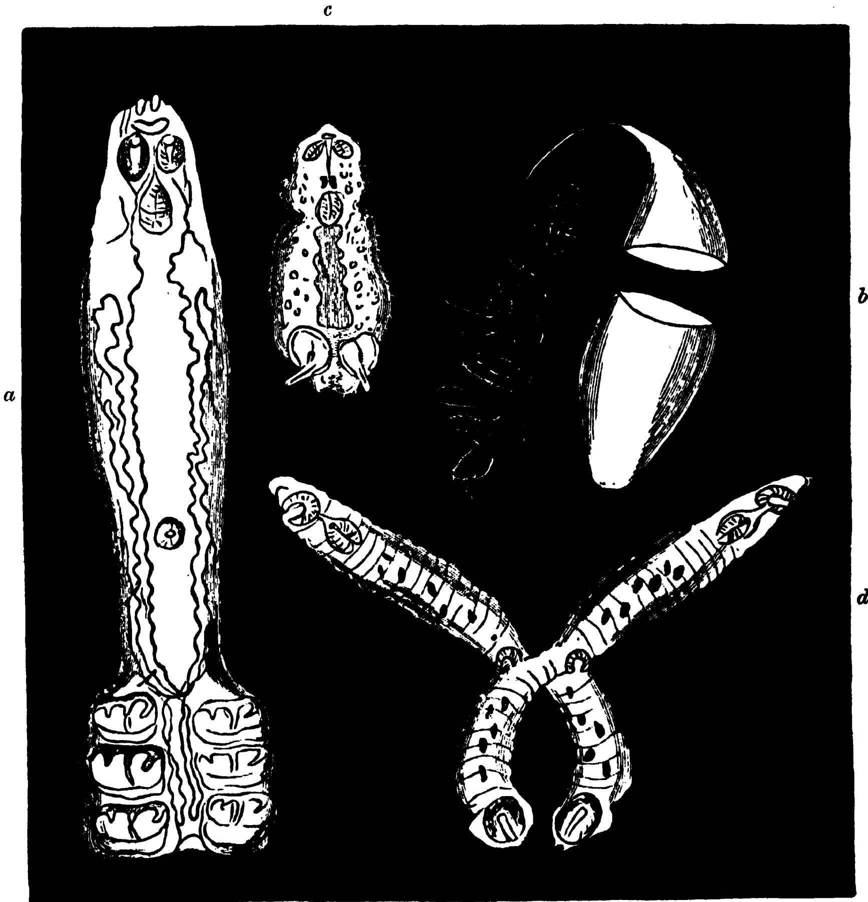
The characteristic feature of this group is the presence in the fore-part of the body of two small sucking-discs, and also of a large one and several small ones at the hinder end, as well as sometimes hooks for clinging. These worms are chiefly external parasites, laying fairly large eggs, and the young develop without an intermediate generation. One of the best known genera is *Epibdella*, in which suckers are placed close to the true mouth, giving the appearance of three apertures of this nature. Fig. 1 of the illustration represents a specimen of one species; in the right-hand figure the head being curled upwards and backwards. The posterior sucker is large and furnished with three hooks; the two anterior suckers are smaller, and behind them is the mouth. This worm is of a whitish colour, and lives parasitically upon plaice and halibut. Nearly related is *Trochopus*, a parasite of the gurnard, represented in Fig. 2 of the illustration, the line to the left hand of the illustration showing the natural size of the animal. On the head, in addition to the two suckers and mouth, are four black spots, lying just in front of the last-mentioned aperture, which are the eyes. The posterior sucker is of enormous size, and rosette or wheel-shaped; it is supported by nine spokes, and surrounded by a fringed border. Fig. 3 of the same illustration represents a species of the allied genus *Cyclatella*, much magnified. This trematode is one of the most striking members of the group. The body is oval, flat, and pure white in colour. At its hinder end it is marked out by a deep notch on each side into three processes, of which the two external ones are wide and lobate, while the middle one forms a slender tail-like appendage, supporting the large circular sucker. This



TREMATODE WORMS.
1, *Epibdella*; 2, *Trochopus*; 3, *Cyclatella*.

organ is supported by a set of radiating spines, eight in number, and has a soft membranaceous rim. The head is surrounded by a circlet of small feelers. This worm—one of the smallest of its group—lives as an external parasite upon annelids, especially upon tube-making forms, such as *Clymene.*

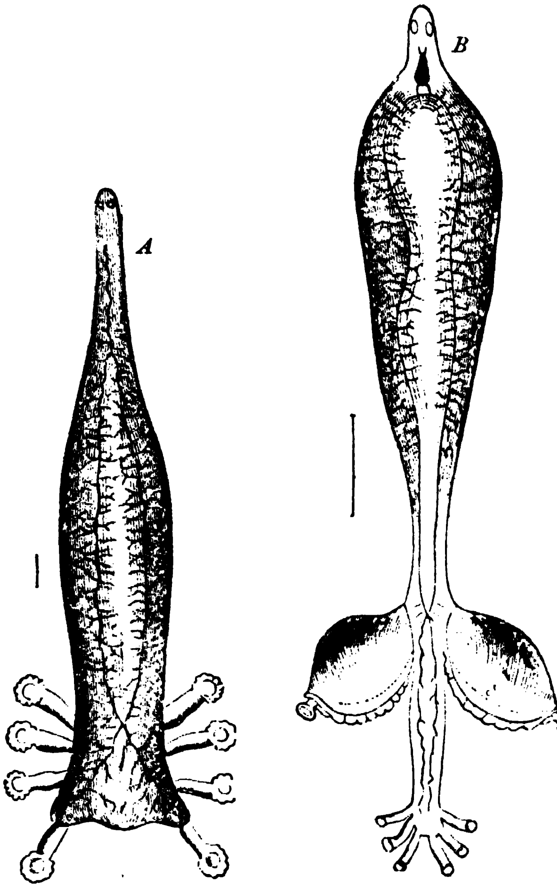
The worms which constitute a second section of the present suborder differ from the foregoing in possessing several sucking-discs at the hinder end of the body. Among them is a curious creature well deserving its name of *Diplozoum*



LIFE-HISTORY OF DOUBLE-WORM (magnified).

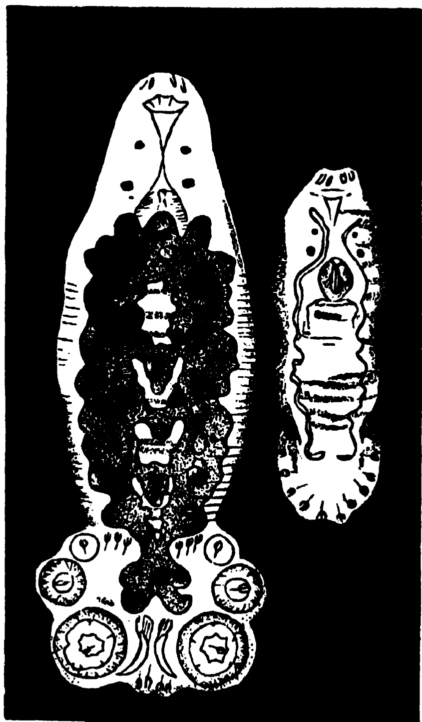
paradoxum, since it consists of two complete, mature similar halves, each possessing every attribute of a perfect animal (*a*). Each of the pointed front ends has a mouth aperture, and close to it a couple of small sucking-discs; while each individual has a separate intestine consisting of a median tube and innumerable side-branches. At the hinder end of the body are two suckers sunk in a depression, and protected by four hard buckle-shaped organs. The double-worm lives on the gills of several species of fresh-water fish, the gudgeon and minnow for instance. The eggs are elongate and provided at one end with a fine thread-like appendage (*b*). In this egg the young (*c*)—which at the time of hatching is only about one hundredth of an inch—takes about a fortnight to develop. It is covered with cilia, has two

eyes, and only a couple of suckers at the hinder end of the body. After quitting the egg the larvæ are very lively and restless in their movements, either gliding slowly hither and thither, or swimming with rapidity. If unable to find the fish in whose gills they are destined to live, they grow feeble and perish; but if successful in making a settlement in their necessary surroundings, they grow into the *Diporpa* (*d*), which is flattened and lancet-like in shape, and bears a small sucking-disc on the under surface, and a conical excresence on the back. After living some weeks or months in this state, and gaining nourishment by sucking blood from the fish's gills, the worms begin to join together in pairs, one specimen seizing the conical excrescence of another by its ventral sucker, then, by means of a truly acrobatic feat, the second twists round until it is able similarly to attach itself to the dorsal excrescence of the first, and in this state an inseparable fusion takes place between the suckers and excrescences involved in the adhesion. Another remarkable trematode is *Anthocotyle merlucci*, parasitic on the gills of the whiting, which is represented in *B* of the illustration. The other worm represented in the same illustration (*A*) is *Dactylocotyle pollacki*, a parasite on the gills of the pollack. Here the slender front end of the body is much longer than in the last, the trunk gradually expands, and is wide and squarely cut at its posterior extremity, upon which are four pairs of long, stout, stalked suckers. The foremost pair of these seem to correspond to the very large suckers of *Anthocotyle*. We now come to two species of the present group of trematodes which, by their manner of life, lead to the second division of the internal parasitic forms. The first of these (*Aspidogaster*), found in the interior of the fresh-water mussels, is little known; but our acquaintance with the development of the second (*Polystomum*) is tolerably complete. This animal, with a roundish body, is less than half an inch in length, and is easily recognisable by the presence at the hinder end of the body of a large wheel-like expansion bearing three pairs of suckers, between the last and longest pair of which are a couple of strong hooks. In the adult stage this worm lives parasitically in the bladder of frogs. It lays its eggs in the spring, and by thrusting itself partially out of the frog's body deposits them in the water. The eggs take from six to



A, *Dactylocotyle*; *B*, *Anthocotyle* (magnified).

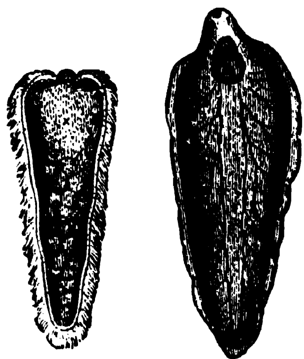
eight weeks to hatch; and the young worm is an active little animal, swimming by means of the cilia with which its body is bordered. It differs from the adult by the presence of the fringe of cilia which extends along the sides of the body from head to tail, and also by the absence of suckers at the posterior extremity of the body. The latter, however, is furnished with eight pairs of hooks, which are retained in the adult. After leading a free life for a short time, the larva attaches itself to the external gills of a tadpole, and speedily loses its clothing of cilia. When the gills shrivel with the conversion of the tadpole into a frog, the larva enters the mouth of its host, and, passing thence into its intestine, succeeds in ultimately making its way into the bladder, where it lives some five or six years before reaching maturity.



Polystomum AND LARVA (magnified).

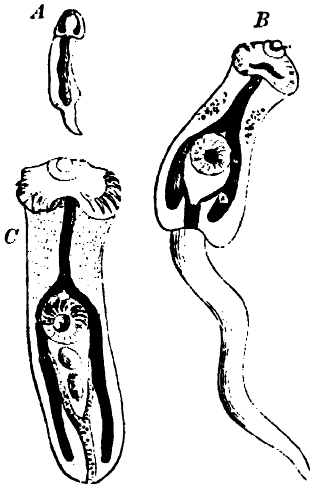
TWO-SUCKERED GROUP,—Suborder **Distomeæ.**

The second division of trematodes is distinguished by the smaller number of suckers, the absence of hooks, and the circumstance that all the members of the group are internal parasites, laying an immense number of small eggs; while in the course of their development the young are inhabitants of more than one host. It is evident that parasites living upon the skin or gills of fish, where they are constantly in danger of being washed away, have much greater need of sucking-discs and clinging-hooks than those living within shelter of some internal organ. On the other hand, it is equally clear that the large number of eggs laid by the internal forms, which pass through a complicated metamorphosis, is a means for providing against the remoteness of the chances of the larvæ meeting with their appropriate hosts. Some of these worms are of importance, on account of the destruction they bring upon the hosts they infest. One of the best known is the liver-fluke (*Distomum hepaticum*), found in the mature stage in the livers of sheep. It is about an inch in length, and nearly half an inch broad. The hinder portion of its body is flattened and leaf-like, but the front is thick and conical, and the outer skin is furnished with many backwardly-directed spines. The eggs—of which it has been computed half a million may be laid at a time—pass into the intestine of the sheep by way of the bile-ducts, and thence make their way to the exterior. Many of these eggs fall upon dry ground, where they

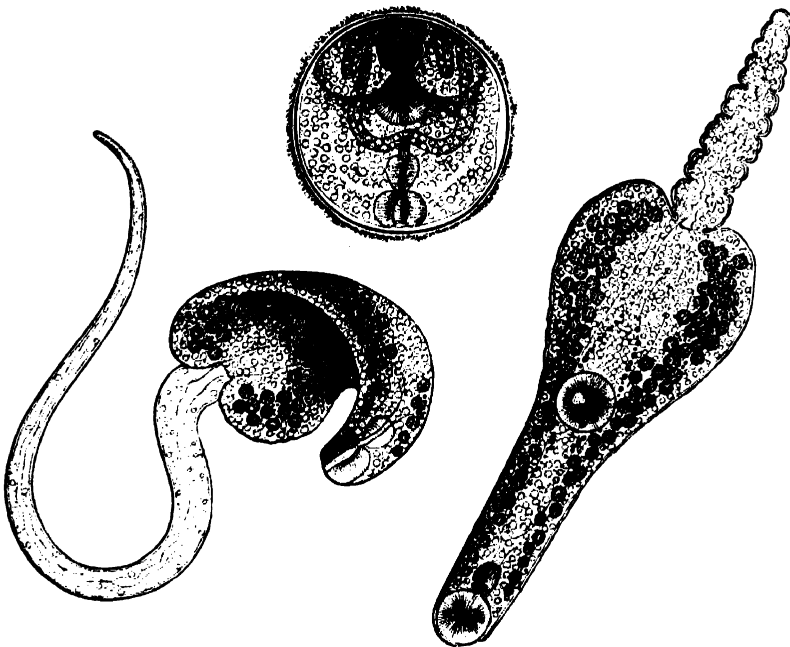


LIVER-FLUKE AND LARVA (enlarged).

perish. Some however, in all probability, make their way into water. When this has taken place, the egg, after two or three weeks, gives birth to a free-swimming, ciliated, conical embryo, provided with a double eye and rudiments of an excretory system. By means of its cilia, this embryo swims rapidly about in search of a particular species of pond-snail. If it fails in its search, it perishes in about eight or ten hours; but, if successful, it proceeds to bore its way into the soft tissues of the mollusc. As soon as it has effected an entrance, it loses its cilia and turns into an oval sac, the *sporocyst*. The latter may multiply by fission, but in any case, in its interior, another organism, called after Redi, its discoverer, *Redia*, arises. This bores its way out of the sporocyst, which closing up again forms another; but if too many are developed they may cause the death of the snail. The *Redia* is cylindrical in shape, and has a distinct mouth and stomach, and in the hinder half of its body there is a pair of bud-like processes, serving as rudimentary feet. The larva in this stage takes up its abode in the liver of the snail, where, in turn, it proceeds to propagate. Its offspring may be a *Redia* like itself but more often it has a different form, and has received the name *Cercaria*.



DEVELOPMENT OF *Distomum echinatum*.


LARVAL FORM OF LIVER-FLUKE (magnified).

It escapes from the parent *Redia* by an aperture situated near the front end of its body; and presents a considerable resemblance to a tadpole, consisting of a long vibratile tail, and a wide heart-shaped body with a forked intestine, two suckers,

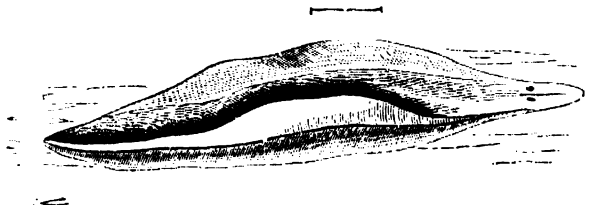
and a gland on each side of the intestine. These larvæ make their way out of the snail, but instead of seeking a new host swim about for a time and ultimately settle upon some water-plant, or a blade of grass in a meadow. Here they enclose themselves in a capsule, and await the chance of being devoured along with the grass by a sheep. From the stomach of the sheep they make their way into the bile-ducts, and there develop into the mature stage.

TURBELLARIAN WORMS—Order TURBELLARIA.

Nearly all the worms of this group lead a free life, parasitism amongst them being the exception. They are found either on the land or in fresh or salt water, and have received the name Turbellaria, or whirl-worms, from the whirling eddies of water caused by the lashing of the cilia with which their unsegmented and flattened bodies are covered. In shape they vary considerably, being either short and oval, or long and worm-like. The alimentary canal is almost always well developed, having a distinct mouth, but never a posterior outlet. There are no special respiratory or circulatory organs, the function of breathing being performed by the entire surface of the skin. The nervous system consists of a large double-lobed brain-ganglion, from which, in addition to some branches passing forwards and outwards to supply the head and eyes, two stout cords, one on each side of the body, run backwards to supply the tail.

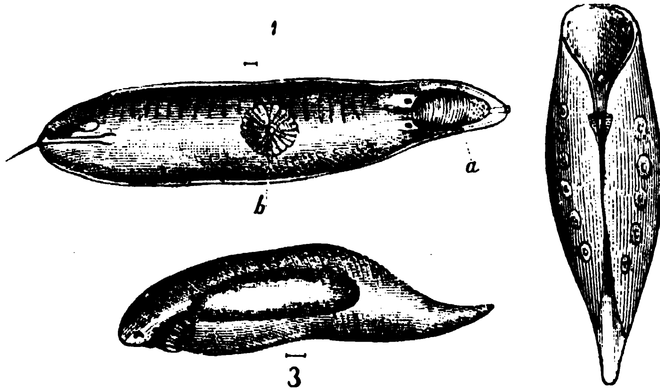
Suborder **Rhabdocœla.**

This group is characterised by the straight and unbranched intestine. A fairly well-known member of the suborder is *Mesostomum ehrenbergi*, a species about half an inch long, found during spring and summer in ponds and streams. The generic name refers to the fact that the mouth, with its muscular gullet, is situated in the middle of the lower surface of the body. Although as transparent as glass and extremely fragile, it is a swift swimmer, moving quietly through the water either by means of its cilia, or by waving the edges of the exceedingly flexible body. It feeds upon fresh-water worms, insects, and crustaceans, its way of overcoming its prey being somewhat curious. The worm converts its body into a cup-shaped hollow, at the bottom of which the mouth is situated, by bringing the two ends close together, and turning over the flexible edges in the same direction. In this manner it envelops its prey, and so deprives it of all chance of escape. It is stated that this and other species ensnare their prey by means of slimy threads. Eggs of two kinds are laid; those found in summer being soft-shelled, while those of winter are protected by a hard and thick coat so as to be able to withstand the unfavourable conditions of this season. An allied species (*M. tetragonum*) is shown in the accompanying illustration.



Mesostomum tetragonum.

Upon the narrow and pointed head are the two little black eye-spots. In the genus *Prostomum* the mouth (*b*) is situated in the middle of the ventral surface, as in the last, but the slender and pointed head-end is provided with a distinct proboscis (*a*), which calls to mind that of the nemertines, inasmuch as it is not directly connected with the mouth, and is contained in a special sheath. The posterior end of the body, on the contrary, is thick, club-shaped, and armed with a sharp goad, which seems to be used as an organ of defence. The same illustration shows a species of the allied genus *Vortex*, in which the aperture of the mouth is on the under side, near the front end of the body. This mouth leads into a large oval gullet, communicating with the long sac-like intestine. The black spot in front of the mouth is the eye. In *Schizostoma*, on the contrary, the mouth which is long and slit-like, is situated in front of the two eyes. Some of the allied genera lead a parasitic and not a free life. For instance, *Anoplodium* is found upon sea-cucumbers, and *Graffilla* upon marine gastropods.



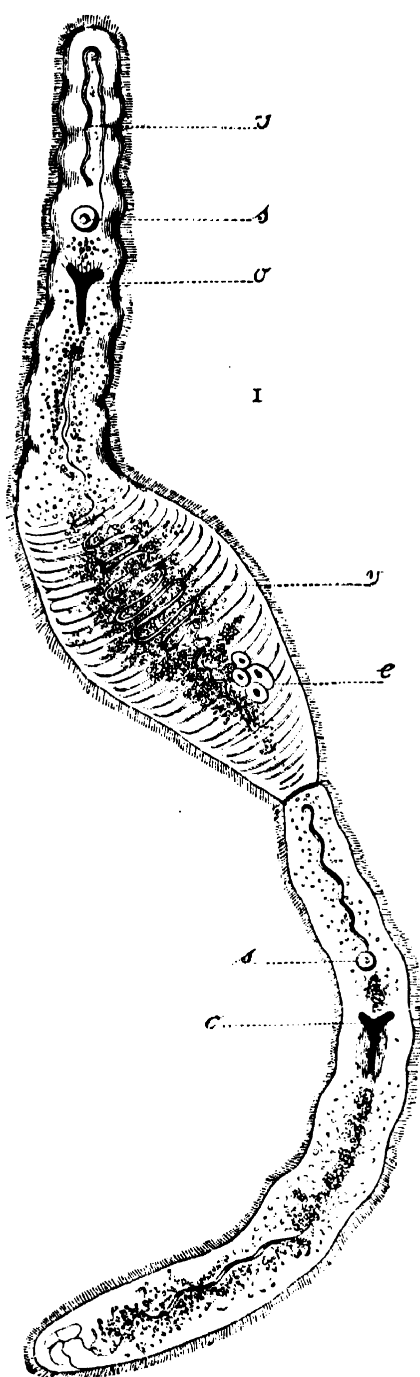
TREMATODES.
1, *Prostomum*—*a*, proboscis; *b*, mouth. 2, *Convoluta*. 3, *Vortex*.
(Natural size represented by lines.)



Schizostoma productum (enlarged 200 times).

Differing in many important points from the typical Rhabdocœla is the small marine *Convoluta*, shown in Fig. 2 of the illustration, in which the alimentary canal, the excretory organs, and the nervous system have disappeared. Imbedded in the solid tissues of some of the species of *Convoluta* are large numbers of cells containing chlorophyll, or the green colouring matter of plants. These cells are probably minute plants (*Algæ*), which have taken up their abode parasitically in the worm. In addition to the ordinary means of reproduction by sexual organs, some of the rhabdocœlans multiply by division.

The accompanying illustration shows one of these worms (*Stenostomum monocelis*) in process of giving rise to a second individual. In the upper half of the figure (*o*) is the mouth, and (*s*) the auditory organ of the parent; the coiled tube (*v*) being part of its excretory apparatus, and (*e*) some eggs. In the lower half (*o*) is the mouth, and (*s*) the auditory organ of the newly-forming individual. The division may begin successively at several places on the body before the last and oldest bud is attached, so that it results in the formation of a chain of segments lying one behind the other.



SINGLE-EYED TURBELLARIAN, *Stenostomum* (much enlarged).

Suborder Dendrocœla.

The members of this division differ from the preceding in having the intestinal canal tree-like, or divided into a number of branches. The mouth, which is situated on the inner surface, leads into a muscular and flexible pharynx, capable of protrusion like a proboscis. The body is broad and flattened, usually broader in front than behind, and generally bears a pair of eyes upon what may be termed the head. In the genus *Polycelis*—the species of which occur in meadows and stagnant water—there are a large number of eyes, the broad front end of the body being bordered with from thirty to fifty of these organs. On the other hand, *Geoplana subterranea*, which lives in sandy and clayey soil, in company with earth-worms, upon which it feeds, is entirely devoid of organs of sight. Many members of the group are inhabitants of the land and fresh water, and are collectively termed Planarians. These are often objects of considerable beauty, being both graceful in movement and decked with various colours. The two-striped *Geodesmus bilineatus*, for instance—which has been found in hothouses in Europe, where it has been doubtless introduced from the tropics with exotic plants—is a dull yellowish colour above, but is ornamented with two reddish brown bands, extending on each side of the back, and meeting near the front and hinder end of the body. Another planarian not infrequently introduced into the conservatories of Europe belongs to the genus *Bipalium*, this species

(*B. kewense*) having been first obtained in the plant houses at Kew. It is a striking creature, measuring upwards of a foot in length when fully extended, and



STRUCTURE OF A DENDROCŒLIAN (enlarged 5 times).

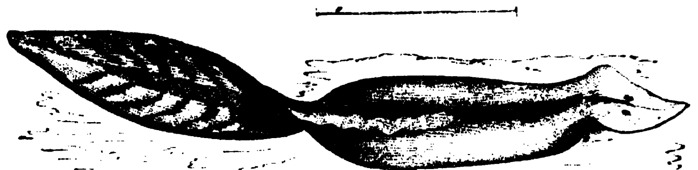
having the grey colour of its skin relieved by three dark longitudinal bands running along the back from the head to the tail. It is exceedingly flexible and contractile, looking sometimes short and stout, and at other times long and narrow. The head is susceptible of many changes of form, assuming the shape of a hammer-head or the blade of a cheese-cutter, and the next moment being tongue-shaped. The skin is richly supplied with glands, secreting a sticky slime, by means of which the *Bipalium* is able to ascend perpendicular surfaces, and to lower itself from a high point by letting out a thread of the material. It is said to feed upon earth-worms, and to propagate by division; the tail-end breaking off and growing into a second individual by acquiring a head, proboscis, and intestine. Land planarians are abundant in the damp tropical forests of Ceylon, South America, and Australia; and a rich population of allied forms frequents the sea. One of the most striking of these marine forms is the tufted planarian (*Thysanozoum*), represented in the illustration on p. 473. Here the back is covered with many rows of dark-coloured tufts; the lower surface being pure white, and the head end furnished with a pair of ear-shaped lappets, in which the sense of touch appears to be concentrated. The creature is shown clinging to a



SMOOTH POLYCELIS.
a, The animal; *c*, The eyes.



TWO-STRIPED GEODESMUS (enlarged twice).



PLANARIAN WORM, *Planaria gonocephala* (enlarged).

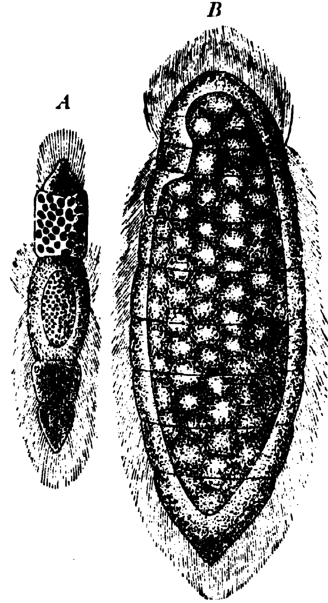
branch of seaweed, with the head elevated so as to exhibit its lower surface, and feeling for a new surface of support. *Planaria gonocephala*, figured above, is one of the land forms. The general structure of the intestine in all the animals of this group is shown in the illustration at the top of the page.

Group of Uncertain Position.

To complete our account of the worms, mention must be made of the parasitic families *Orthonectidæ* and *Dicyemidæ*, of which the serial position is uncertain.

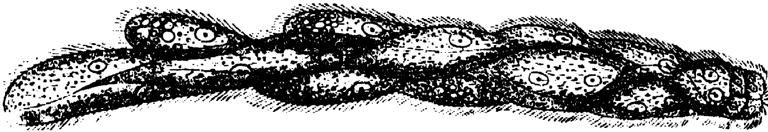


TUFTED PLANARIAN, *Thysanozoum* (enlarged twice).



Rhopalura. *A*, Male; *B*, Female. (Very much enlarged.)

The members of the former inhabit the body-cavity of certain turbellarian and nemertine worms and brittle-stars. They are minute, segmented creatures, scarcely exceeding the twentieth of an inch in length, and without digestive organs or nervous system, but with the skin ciliated. The males are smaller than the females, being in the figured *Rhopalura* only about half the size of the latter. The *Dicyemidæ* are ciliated, thread-like parasites, varying in length from about a thirteenth to a fifth of an inch in length,



A DICYEMID (enlarged 20 times).

and living in the kidneys of cuttle-fish. The body consists of a central portion, composed of a single long, fusiform cell, around which is arranged a series of whiter cells, partly projecting like papillæ from the surface. At the front end the cells of the external layer form a symmetrical head, by which the parasite attaches itself; but there are no distinct nervous, digestive, or muscular organs.

R. I. POCOCK.

CHAPTER XIV.

JELLY-FISH, CORALS, AND SEA-ANEMONES,—
Subkingdom **CŒLENTERATA.**

FEW have been able to revel in the exquisite beauty of the southern coral islands, which through thousands of years have been slowly piled up to the surface of the water by the coral-animals. The vivid colouring of the fauna in the lagoons of those marvellous islands is not to be found in European seas, but even in these less favoured climes, any observant traveller, as his ship passes through calm water, may notice lovely creatures nearly related to the corals. Who, for instance, has not seen exquisitely coloured transparent jelly-fish, floating just below the surface, and propelling themselves by alternately expanding and contracting their bells? Or who that has kept a marine aquarium has not admired, as its greatest ornament, the sea-anemones? These animals, the corals, the jelly-fish, and the sea-anemones, constitute the great group known as Cœlenterata. The group comprises all those creatures in which the internal cavity, corresponding with the alimentary canal of other animals, is not a closed canal running through the body, but is commensurate with the whole cavity of the body. Consequently there are no spaces answering to the body-cavity of the Vertebrates, between the wall of the alimentary canal and the outer wall of the body.

A study of the earliest growth of the Cœlenterates has shown that their internal cavities are nothing more than regular radiate outgrowths of the intestine, and, like the latter, come from the primitive intestine of the larva. The result of this development is a condition which does not occur elsewhere in the whole animal kingdom. We have no separate digestive canal, no closed blood vascular system, and no specialised respiratory apparatus. There is only a system of cavities, all in open communication with one another, occupying almost every corner of the body.

Again, the Cœlenterates are radiate in structure, that is, when seen from above, they are typically star-shaped; and if a Cœlenterate be cut across, every horizontal section shows a symmetrical arrangement of the parts around a centre. There are other radiate animals, such as the Echinoderms, but while in these five is the fundamental number of rays, in the Cœlenterates the rays are often far more numerous, being some multiple of four or six. Again, while the skin of the former is almost always modified into a skeleton, or is thick like leather, leathery skins are the exception in the latter. When the Cœlenterates do form calcareous skeletal structures, these are quite different from the tests of the sea-urchins; and, in all cases, the anterior end of the body, crowned with one or more circles of tentacles, remains soft and flower-like. The most highly developed of the free forms, how-



NOPHORES

ever, such as the sea-anemones and the jelly-fish, have no hard skeleton at all, but are amongst the most delicate and beautiful objects in the realm of living nature.

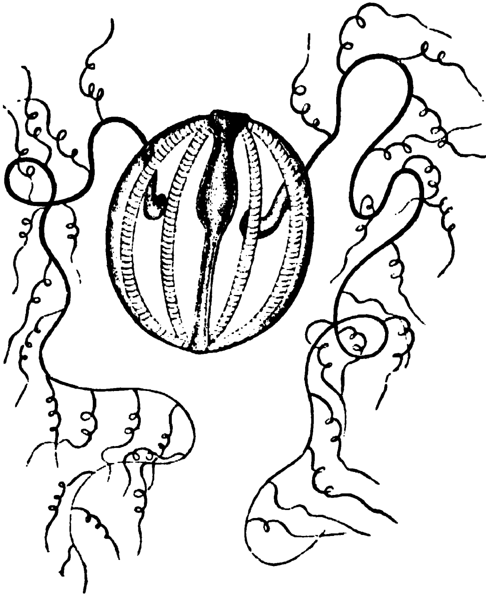
In spite of the variety of forms to be found, the Cœlenterata are almost as incapable of higher development as the Echinoderms. Like the latter, they have failed to make any way in fresh water, not to speak of the land. A few free-swimming jelly-fish, a minute attached polyp, and some degenerate sponges are, indeed, found in fresh water, but these can hardly be looked upon as successes. While, at present, it is not easy to connect the Cœlenterata with any other group, inasmuch as they appear to stand without any near relatives among the higher animals, they have a special interest, since they are considered to represent a stage in the development of animal life through which all the higher forms have passed. Some simple form of Cœlenterate may have given rise to all the higher animal forms, the modern Cœlenterates—the sea-anemones, corals, etc—being those descendants of the primitive simple form which have retained the original type of organisation almost unchanged.

THE CTENOPHORES,—Group CTENOPHORA.

Although all are agreed that the so-called Ctenophores are members of this subkingdom, their exact position is not clear. The Ctenophores are glassy, transparent creatures, either shaped like apples, melons, or Phrygian caps, or else forming bands, often a yard in length, and thickened at the middle. Several types are shown in the coloured Plate. The marvellous transparency of all but one (*Beroë*) is specially remarkable. They inhabit the open sea, or are driven by currents and winds near the coast and into harbours. Their position in the water is usually more or less vertical, the mouth being turned downwards. The organs from which this group takes its name are the ribs, which either run from pole to pole, or else only for certain distances along the meridians, which are often symmetrically arranged. These ribs consist of rows of short transverse combs, each being formed of a row of cilia. The cilia forming a comb are connected together at their bases, but are also capable of independent movement. As they wave to and fro, they constitute what is called a swimming or rowing plate. The activity of these rows of plates depends upon the will of the animal, which can move either the plates of a single rib, or all the ribs together; this latter movement resulting in slow locomotion in the direction of the apical pole, *i.e.* the pole turned away from the mouth. The body is capable of various swift, light, and graceful movements, for in addition to the rowing plates there are other structures, such as the oral umbrella and the capturing filaments or tentacles, with their hair-like branches. These tentacles, which are attached like arms at the sides, are capable of erection, or of withdrawal into pockets. There is great variety in the development of these accessory organs of locomotion. For instance, the *Cydippidæ* have only arms, which, with their branches, serve for capturing food as well as for steering. In other orders, vertical, oar-like, dermal folds stand out from the body, by means of which the movements become more rapid and energetic. Some species of *Eucharis*, by suddenly shutting up the oral umbrella, can jerk themselves forward; and when successive jerks of this sort cause the body to move with

greater speed than usual, the arms are withdrawn into their pockets or stretched backward like a rudder. This power of free locomotion necessitates some regulating organ, so that the desired direction or position of the body may be maintained. Such an organ exists at the apical pole of the body, and may be described as consisting of a small weight borne on springs, by which the oscillations of the body or deviations from the line of movement can be instantly felt.

The ventrally placed mouth is like a large slit between the folds of the umbrella, and leads into a stomach which is either tubular or flattened. The food is digested in this stomach, the indigestible parts, mixed with mucus, being again ejected through the mouth. The upper end of the stomach is in direct communication with a funnel-shaped space of variable width. From this funnel-like cavity canals arise, which branch and run below the outer surface, following the lines of the ribs. This funnel further possesses an aperture of its own, opening on the exterior, in the region of the apical pole. Within the funnel is found a fluid substance containing particles of the food-pulp drawn in from the stomach, but consisting chiefly of water, taken in voluntarily; this fluid being kept in motion by ciliary action through the canal-system. Although water is also sometimes taken in through the proper apical aperture of the funnel, this aperture seems principally to serve for the ejection of the fluid when of no further use. It is then also mixed with waste matters from the body. Stinging-cells, such as occur in the next group, have as yet been found in only one species of Ctenophore (*Haeckelia rubra*), and then only in small numbers. Instead of stinging-cells, the Ctenophores have adhesive cells, or small hemispherical knobs found on the tentacles or capturing filaments; these being provided with elastic, spirally-coiled stalks, but containing no poison. These knobs are beset with sticky globules, to which small animals, such as minute crustaceans easily become attached. If the prey attempt to escape, the spiral thread by which the knobs are attached becomes stretched. When the thread is withdrawn, it more or less entangles the victim, and, being like the knob, provided with a great number of sticky particles, renders escape impossible. These structures are very different from stinging-cells, which are useless to an animal after having been once employed. An adhesive cell or knob can act apparently any number of times, being each time drawn back by the spiral thread to its former position.



CYDIPPE (nat. size).

Ctenophores feed upon all kinds of small pelagic animals, especially Crustaceans, while they themselves fall a prey to the disc-shaped jelly-fish and sea-anemones. Ctenophores may continue to grow, if uninjured, almost indefinitely,

or as long as life lasts. Storms, however, destroy them. The largest specimens are, as a rule, found in waters sheltered from the wind. They are to be seen throughout the whole year, but are most plentiful during the spring months, and become rarer towards summer, when some species, such as the Venus' girdle, almost completely disappear. In the early autumn, however, great swarms appear, especially of *Cestus* and *Beroë.* After a spring of active fertility, the larvæ, at the beginning of the hot months, sink down to greater depths, where they grow into adults, and come to the surface again in swarms in autumn.

Insignificant as these delicate creatures may appear, they delight the eye, both while living and after death, by their luminosity. This is principally displayed in the walls of the canals below the ribs. It is a curious fact, and one unique as regards luminous marine animals, that Ctenophora, after being exposed for only a short time to the light of the sun or the moon, or to artificial light, when suddenly brought into a dark room, are incapable of giving light. Allman is of opinion that the *Beroidæ* and their broods must be regarded as the principal source of marine phosphoresence on the English coast.

The Ctenophora are hermaphrodite; sexually mature animals of many species being found throughout the whole year, while others occur only in spring, summer, or winter. The young pass through a metamorphosis, or have larval stages which precede the definite form. In at least one species (*Eucharis multicornis*) sexually mature larvæ, or larvæ which are capable of reproduction as such, also occur; these, when completely developed, become once more capable of reproduction as adults;—a method of multiplication which has been called dissogony.

The most interesting, if not the most beautiful, of the Ctenophora are the *Beroidæ,*—shown in the coloured Plate,—which resemble Phrygian caps in shape. In section, they are oval; the mouth is wide, and they have no capturing filaments or tentacles, and therefore no adhesive cells. They attain a size of 8 inches, and are of a delicate red colour, which appears marbled. This appearance is due to the branching of the eight principal canals above described, the ramifications forming a network. *Beroë forskalia,* shown in the Plate, is found in the Mediterranean. The *Beroidæ* are carnivorous, feeding on their own relations of other genera. On one occasion, a large *Eucharis* was placed in a basin with a *Beroë forskalia,* not half its size, in a fasting condition. The latter, attracted by its wonted food, began swimming round the *Eucharis* in large circles, with wide open mouth. On approaching its victim, it darted at it, and seized it. The swimming-plates of the *Eucharis* beat helplessly, when, to the astonishment of the observers, this large creature was completely mastered by the *Beroë,* which in less than a quarter of an hour succeeded in swallowing its victim, and, distended like a balloon, lay at the bottom digesting it.

The *Cydippidæ* are conical, or barrel-shaped, with the ribs uniformly developed, and two opposite tentacles, one on each side. The beautiful creature figured in the Plate is *Hormiphora plumosa* from the Mediterranean. The remarkable Venus' girdle (*Cestus veneris*), shown in the annexed illustration, is so called because the body is lengthened out sideways like a ribbon, so that the mouth is found on the under edge of the ribbon half-way along it. This girdle-shaped, transparent creature, iridescent in the sunshine, is a dazzling sight. The ribbon is edged with

cilia, corresponding with the ciliated combs of the body proper. An additional charm is added to this beautiful form by its lively graceful movements, the ribbon assuming all possible curves. If roughly touched, it rolls up spirally, beginning at one end. When undisturbed, its ribbon-like outgrowths are sometimes stretched out, sometimes more or less rolled up, or else the one is rolled up and the other extended. It can, like other Ctenophora, keep itself in motion by the mere play of its cilia, but it also uses the undulating movements of its ribbon-like body. The transformation of the larva after leaving the egg is complicated. The



VENUS' GIRDLE (½ nat. size).

young larva is shaped like a balloon, and possesses two principal tentacles provided with lateral filaments; it has further, on each rib, four to five swimming-plates. At this stage this larva resembles the adults of some other species of Ctenophora, and only by degrees, after passing through many other stages, assumes the form of the girdle.

STINGING SERIES,—Group CNIDARIA.

The Cnidaria, or stinging Cœlenterates, which comprise the sea-anemones, corals, jelly-fish, and the little hydra of English ponds, receive their name from the so-called stinging-capsules, found in their skin, which may be regarded as the homologues of the adhesive cells of the Ctenophores. Before describing these offensive and defensive weapons, it is necessary to obtain some idea of the animals which use them, these Cnidarians having departed less from the simple Cœlenterate type than have the Ctenophora, in which this type is much disguised. Imagine,

then, a long footless stocking, sewn up at each end. By thrusting one-half of this stocking into the other half, there would be obtained a long bag with a double wall. Suppose this bag fixed by its blind end to the ground, while the open mouth-end stood up in the air, to catch anything that fell into it, and then suppose that, close round the mouth, the double wall grew out into arms or tentacles, which could catch anything passing and draw it into the mouth, then we should have a structure somewhat resembling the fundamental form of the Cœlenterata. But it must further be supposed that the two woollen walls of the stocking are replaced by two layers of living cells, so that the outer one forms the skin, which is armed with the stinging-cells, while the cells of the inner layer are hungry creatures waiting to digest anything digestible which comes down into the bag. This is still not enough, as the whole animal must be able to move its tentacles, and to stretch or contract its body; so that between the layers there is a special gelatinous layer in which run muscle and nerve fibres. Further, in order that the tentacles, when they seize a passing animal, may have no trouble with it, but may be able to bring it to the mouth as easily as possible, they are thickly covered with batteries of stinging-cells. But how, it may be asked, can we get the beautiful bell-shaped jelly-fish from such a creature? The imaginary animal just described was fixed to the bottom of the sea, or to weeds and stones under water, and here it would grow. But there is a law of life that, after a certain size has been reached, further growth does not add to the animal's stature, but takes the form of buds, which may either be cast off as eggs to hatch and develop elsewhere, or may remain attached to and branching out from the parent animal. Both these processes take place in the simple Cnidarians. Some branch and rebranch to form beautiful trees, or stocks, made up of living animals. Now if all these animals were to drop eggs which fell to the ground to grow up around the parent stock, so fast would they grow that they would soon be killing one another through overcrowding. Hence it has come to pass that in many forms only a certain number of the animals forming a stock produce eggs, and these are able to break away and swim off with their load of eggs, to drop them far away. In this way, swimming-bells have been produced, originally only as carriers for scattering eggs broadcast, just as many trees have arrangements for scattering seeds as far as possible from the parent stem. From this beginning, all the race of jelly-fish appear to have sprung. The free-swimming life offered new fields for catching food. Myriads of small creatures swim near the surface of the water; the Cnidarian fixed to the bottom of the sea may stretch its arms in vain for these, while the free-swimming bell can go amongst them and follow them along the surface currents, feeding as it goes. Hence, while the eggs of many jelly-fish when dropped develop first into fixed tree-like stocks, which, when grown, let loose another swarm of jelly-fish, the eggs of others, as if to save time as it were, and impatient of the fixed tree-like stage, hatch out at once as young jelly-fish, which rise at one bound to all the free-swimming privileges of their immediate parents.

The former process is termed alternation of generations; the egg producing a stock, which is one generation, the stock producing a jelly-fish, which is a second; and these two alternating. In the latter case, when a jelly-fish produces a jelly-fish, one generation—the stock—has been suppressed. This is important, since there

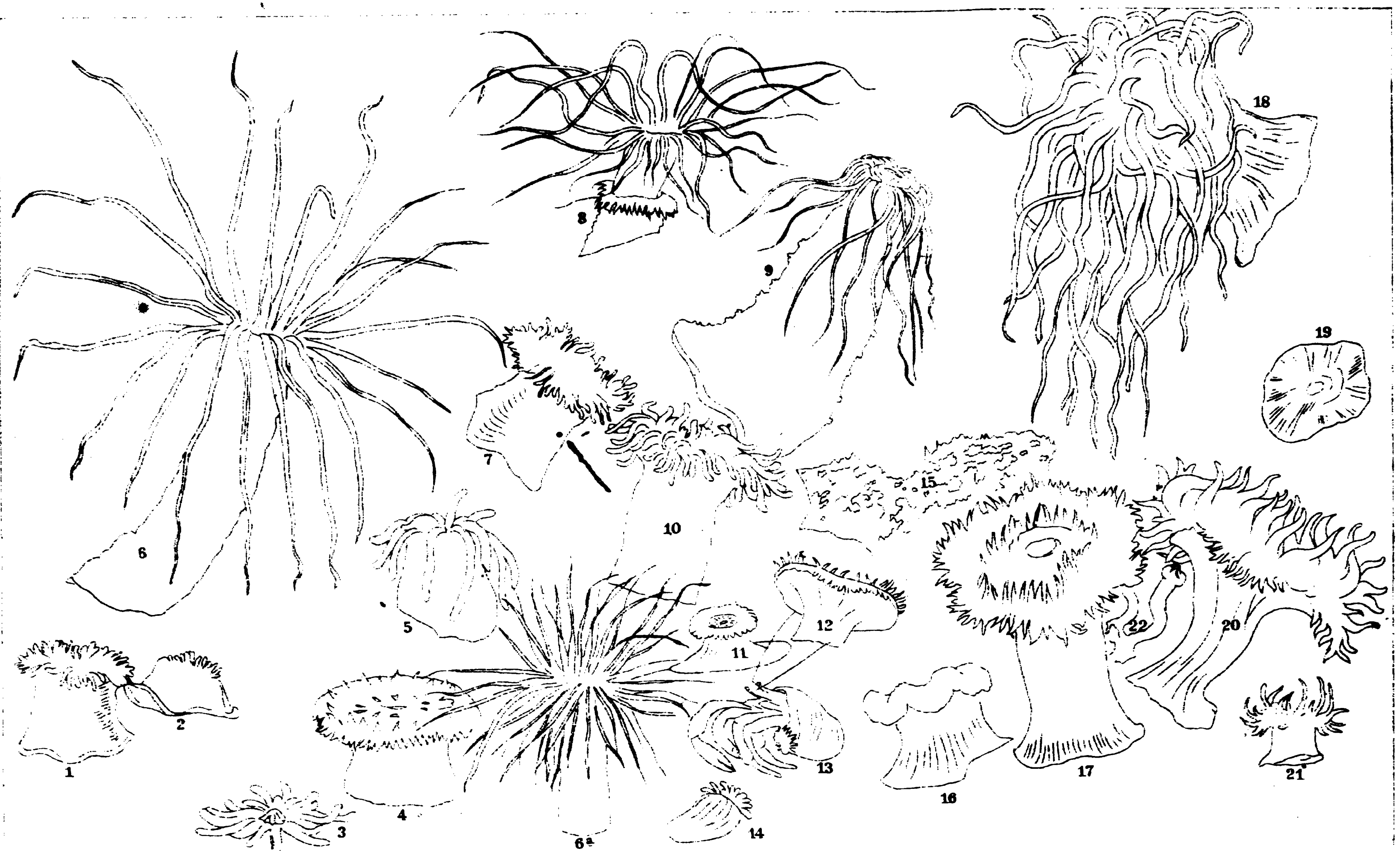
is evidence that this alternation of generations was, and indeed still is, widely spread in both the animal and the vegetable kingdoms. It is however, as a rule, suppressed, as animals rise in the scale of organisation. The Ctenophora are a highly developed group in which this alternation of generations has been suppressed.



STINGING CAPSULES.
1 and 2, With retracted filament; 3, Partly protruded 4 Fully protruded. (Highly magnified.)

One word as to the changes necessary to turn the simple Cnidarian above-described into a bell or umbrella-like jelly-fish. The principal change is in the gelatinous layer between the outer skin-wall and the inner stomach or digesting layer. This middle layer develops into an enormous mass of glassy jelly of such a shape that, instead of the body being long from the mouth (oral pole) to the bottom of the sac (aboral pole), the animal is umbrella-like, the mouth being under the bell, while the top of the bell corresponds with the old base by which the parent polyp was attached to the ground.

Before taking the principal forms assumed by the Cnidaria, and briefly describing their relation to one another, the stinging-cells and batteries claim attention. These cells, though all microscopical, vary considerably in size, without their structure being essentially affected. The surface protoplasm of the cell is modified into a tolerably firm shell, enclosing an oval or cylindrical vesicle. Closely associated with this structure is a pointed process, standing up far above the level of the skin, known as the cnidocil. Within the vesicle is found, either spirally rolled or in an irregular tangle, a long filament, or hollow tube, which is a prolongation of the vesicle, but turned outside in. This tube, which is more than twenty times as long as the cell, is pointed at the tip, and almost up to the tip beset with two rows of fine, spirally-arranged, barbed hooks. When the cnidocil is touched or irritated, this filament is violently shot forth, being turned inside out like the finger of a glove.



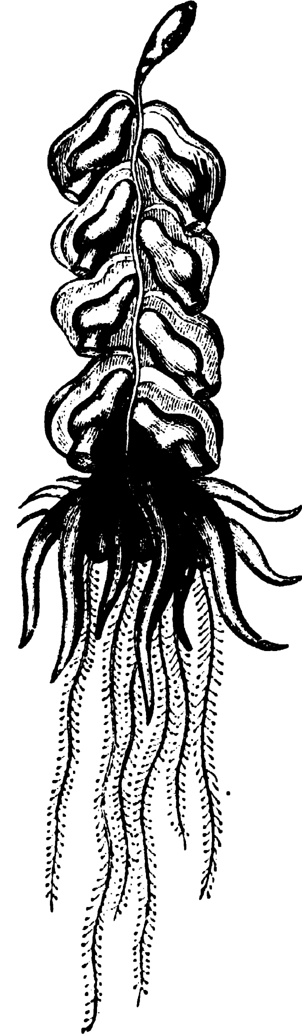
1, 2. *Actinia equina*. 3, 5, 14. *Eloactis mazelii*. 4. *Ragactis pulchra*. 6, 6a, 8. *Cerianthus membranaceus*. 7, 19. *Actinia cari*. 9. *Cladactis cortae*. 10. *Cereactis aurantiaca*. 11, 12, 16, 17. *Heliactis bellis*. 13. *Adamsia palliata*. 15. *Astroides calycularis* (a coral). 18. *Anemonia sulcata*. 20. *Aiptasia mutabilis*. 21. *Bunodes*. 22. A Tubicolous Worm.

So long as the thread remains rolled up within the vesicle, the barbed hooks are, of course, in the tube, but when it is shot out, they come on the outside. The rolled-up thread appears to be filled with some poisonous substance, which, when the tube is shot out, is ejected over the spot where the point strikes and wounds. It has been asserted that in many, probably in all, Cœlenterates, muscle and nerve elements occur below, and are associated with, the stinging-cells. The action of these stinging-cells is perhaps as follows. The cnidocil is touched by some passing object, and conveys the stimulus which leads to the violent contraction of the distended vesicle. This forces out the tube which is lying in it, in the manner described. A simple touch is, however, not enough to cause the cell to be discharged, otherwise such discharge would take place when the animal knocks against a stone, or when the tentacles, being withdrawn, touch the body. We must assume that the Cnidaria are able to distinguish between the various stimuli received from contact with other bodies. The stinging-cells are very often grouped together to form so-called stinging-batteries of various sizes. Dr. Möbius writes that as soon as the capturing arm touches the passing victim, the long filaments are shot out of the stinging-capsules, penetrate or adhere to the animal and detain it. Unless the prey is stronger than its attacker, it cannot escape. New filaments are being continually shot out at it as it is slowly drawn in towards the mouth; even within the body-cavity similar stinging-cells are found in the skin. The greater the struggle, the larger the number of capsules discharged, in order to hold the prey.

THE JELLY-FISH AND THEIR ALLIES,—Class **Polypomedusæ**.
Order SIPHONOPHORA.

We have already described the swimming-bells of the jelly-fish as the highest development of the stinging group. The Siphonophora, as represented by the Portuguese man-of-war, are, in their turn, the highest development of the swimming-bells. They are, in fact, colonies of bells, joined together in almost every possible way, and showing extraordinary modifications of individuals in the interests of a division of labour. For instance, some of the bells do nothing but row the colony along, others feed the colony, others are guards, and yet others produce the eggs. As our first example of the group, we may take the creature known as *Physophora*, which consists of a long tube or central axis, surmounted by an individual which is nothing but an air-vesicle for holding the colony in an upright or a sloping position in the water. Below the air-vesicle come two rows of bells, which bring about by their contractions the movement of the whole colony. These rowing-bells force the water out of their cavities, and thus propel the colony. Below these, again, comes a circle of extremely mobile tentacles, which may perhaps be the tentacles of vanished bells. Among these tentacles are hollow structures, open at the end, which are the feeding-bells, now reduced to sucking-tubes, or stomachs, each of which endeavours to seize and digest for itself whatever in the shape of food (chiefly small crustaceans) is brought to it by the long capturing filaments and their branches, armed with stinging organs. The colourless blood and nutritive fluid prepared by these two stomachs serve

for the nourishment of the whole colony, and are carried to the various parts through the axial tube above mentioned. In the illustration, which has been chosen on account of its comparative simplicity, no reproductive or egg-bearing bells are shown. When present in the *Physophora*, these appear like clusters of grapes; in other genera they are capsules; in others, again, they may be actual swimming-bells, which become detached, and lead an independent life. This fact is of importance in helping us to understand this complicated organism. It shows that the *Physophora* is not a single animal, but a stock or colony. Of this there is evidence in the rowing-bells, as well as in the two, three, four, or more sucking-tubes, with distinct mouths and stomachs. And, lastly, we have the reproduction brought about, in some cases, by detached jellyfish-like individuals. All the parts of the organism form a whole in a physiological sense; they belong to one life, and many are so modified as no longer to appear as individuals. But, on the other hand, some of them are fairly independent, and, when they take the form of medusæ, they are so highly developed that their individuality is at once manifest. We must, therefore, regard a Siphonophore as a colony of highly-modified individuals, which—owing to the fact that these individuals differ greatly in form and function—constitute what is termed a "polymorphous colony."

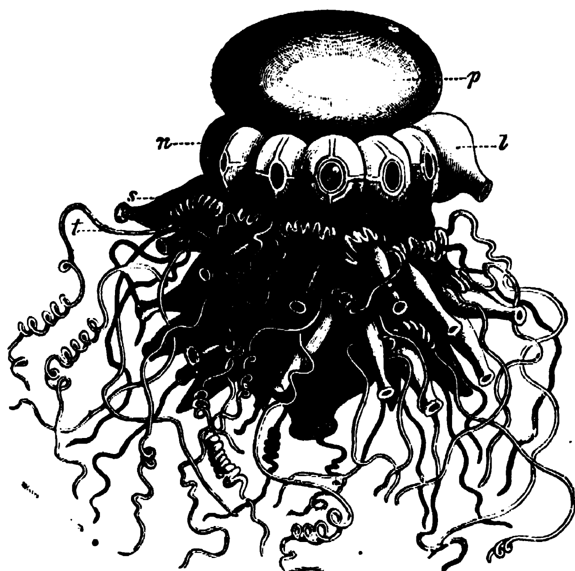


Physophora, WITH TWO ROWS OF SWIMMING BELLS (nat. size).

One of the most beautiful and most dangerous of the Cœlenterata belongs to the Siphonophora. This is the so-called Portuguese man-of-war (*Physalia*), several species of which are found in the southern seas. The air-bladder at the top of the stem is a large, oval vesicle, which projects above the surface, lying horizontally on the water. It is drawn out into two points at opposite poles. A comb runs lengthwise and somewhat slantingly along the top of it. From its lower side, nutritive polyps, feelers on which the genital products develop, and very long tentacles hang down side by side below the surface of the water. Another strikingly beautiful species found in the Mediterranean is *P. pelagica*. Lesson writes that these creatures "shimmer with the most splendid colouring. The air-bladder and its comb look like molten silver, adorned with light blue, violet, and purple. The small thickenings on the keel of the comb are of a vivid carmine, while the appendages are of a wonderful, delicate, ultramarine blue." The English name is happy, as it indicates the latitude in which the traveller from Europe first meets with it, its ship-like appearance on the surface of the water, where it uses its comb as a sail to catch the wind, and its ample provision of weapons. The tentacles of the *Physalia* are stiff with batteries of stinging-capsules, and those who are careless enough to touch them will repent. Meyen

relates that during the first voyage round the world made by the ship *Princess Louise*, a sailor jumped into the sea to capture a large *Physalia*. As he seized it, the animal enveloped him in its long filaments, stinging him so terribly that he cried out for help, and was hardly able to swim back to the ship to let himself be hoisted up. Severe inflammation and fever followed, and his life was for some time despaired of.

During the *Challenger* expedition, deep-sea Siphonophora of a remarkable kind were brought to light. The most interesting belonged to a new family, the *Auronectidæ*. The colony, instead of being a long string of individuals, is here thickened and shortened so as to be oval or round. It consists of a hard, cartilaginous mass, traversed by a close system of branching canals. The upper part of this mass is a large, round, hollow air-bladder (*p* in the figure). This pneumatophore is surrounded by a circle of large, round swimming-bells (*n*), one of which (*l*) is modified in a remarkable way. It is not, like the rest, quite hollow, but is traversed by a narrow canal attached to its walls by strands of gelatinous tissue. The free end of the canal opens outward through a short tube, while its attached end enters the great bladder of the pneumatophore. This specially modified rowing-bell has been called the aurophore, since it appears to regulate the quantity of air in the air-bladder. In order to sink to a greater depth, the *Stephalia* has only to contract its pneumatophore, discharging the air through the lateral canal. When the animal rises, the aurophore probably secretes a gas which fills the pneumatophore again. The lower end of the colony is occupied by a large feeding or nutritive polyp, and at its sides there are several rows of smaller nutritive polyps (*s*), each of which, at its base, carries a capturing filament (*t*), and at its side grape-like clusters of reproductive bodies.



Stephalia (nat. size).

The Siphonophora, as a rule, require frequent changes of depth. It does not appear that exclusively deep-sea forms are to be found in the Mediterranean, but that all Siphonophora under certain circumstances and at certain seasons appear at the surface. Many pass through their larval development at a great depth, and the young *Physophora* larvæ found at the surface in the spring descend to greater depths at the commencement of summer, and only return, when their metamorphoses are complete, to develop into sexually mature animals. In the *Physophoridæ* we had the different individuals in a long series. In the *Auronectidæ* we found them arranged in a compact mass; and, lastly, in the *Velellidæ*, the body is flattened out to a disc, which is traversed by a system of canals. On

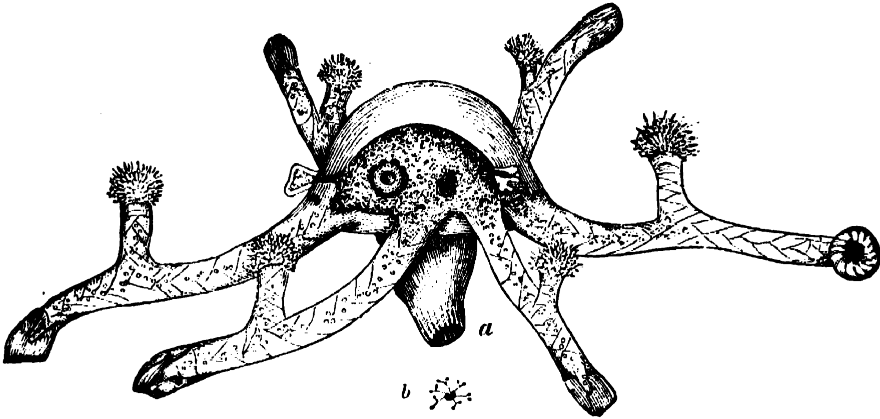
this disc lies the similarly shaped pneumatophore, which is also traversed by concentrically arranged canals opening outwards. The polyps hang on the lower side of the cartilaginous disc, a large nutritive polyp occupying the centre, surrounded by concentric circles of smaller nutritive polyps. As in the *Auronectidæ*, these polyps carry at their bases genital clusters, but no capturing filaments. The tentacles are arranged round the margin of the disc, and are very short. The genus *Velella*, one species of which is frequently found in the Mediterranean, has an irregular oval disc, surmounted by a sloping comb, which acts as a sail. These animals, which are of a deep indigo colour, are often found in swarms.

Order HYDROMEDUSÆ.

Having considered the complicated colonies of swimming-polyps constituting a Siphonophore, the individuals of which have each been simplified for the performance of a limited number of duties, we turn to the solitary swimming-bells, each one of which forms an individual competent to perform all the many functions required in its struggle for existence. There are hosts of these bells, of almost all sizes, some being large and beautiful, but dangerous to touch, while others are quite minute creatures, which have to be examined under the microscope. In regard to these swimming medusæ, it has been already mentioned that they were primitively individuals broken loose for a free-swimming life in the open sea from a stock attached to the ground at the bottom. The eggs of some of these forms have now given up passing through the attached stage, and hatch out at once as young medusæ. Now, examination has shown that this host must be divided into two groups, having remarkable differences, the one being called the Hydromedusæ, and the other the Scyphomedusæ. The two came from two different kinds of attached stocks, and consequently, as free-swimming animals, in spite of their general resemblance to one another as jelly-fish, each has organs which the other wants. Taking the Hydromedusæ first, as closest to the Siphonophora, we describe a few in detail, in order to give a clearer idea of the alternation of generations.

Among the Hydromedusæ there are the following different life-histories. Beginning with the highest, we have—(1) jelly-fish alone, the eggs of which have given up forming stocks, but hatch out jelly-fish; (2) jelly-fish, the eggs of which still form stocks, some individuals of which swim away as jelly-fish; (3) stocks in which the sexual individuals do not swim away as jelly-fish. We need not here describe any of the medusæ in detail, since the much larger jelly-fish of the Scyphomedusæ will claim our attention presently, but two remarkable forms, which have taken to creeping on the ground, deserve attention. In Dalmatia, on seaweed, a delicate, pale object can often be discerned with a magnifying-glass creeping laboriously about on its long arms. If detached from the seaweed, it falls to the bottom, as it is unable to swim. In each point of its structure this animal is a medusa, related to the genus *Eleutheria*, or *Cladonema*, but still further removed from the ordinary medusa in one respect, since the *Cladonema* alternately swims and creeps. This creeping medusa (*Clavatella prolifera*) has six arms, the tips of which are provided with true suckers. On these it walks, as on stilts, while from

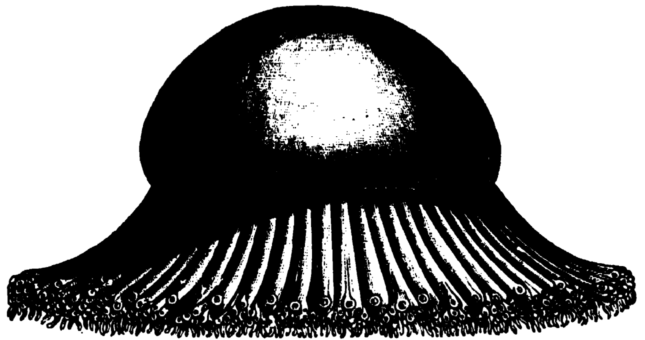
each arm a short stalk rises, the swollen end of which is beset with stinging-capsules. The very extensile mouth-tube moves about tentatively, and easily seizes upon the small crustaceans to be found upon the seaweed. Just above the base of each arm lies a horseshoe-shaped eye-spot containing a well-developed lens, but so far the nerve belonging to a true eye has not been discovered. Somewhat higher up, between every two arms, a bud is to be found. None of the



Clavatella (*a*, magnified ; *b*, nat. size).

specimens of a certain size examined in May were without their six buds, these being at such different stages of development that their gradual growth could be clearly traced. On the riper buds the rudiments of a second generation of buds were to be seen. Multiplication by budding has been observed in other medusæ, and it is from such budding medusoid colonies that we may perhaps deduce the remarkable swimming colonies of the Siphonophora. As a rule, however, all medusæ multiply sexually by means of fertilised eggs; even the *Clavatella* at other seasons lays eggs.

Creeping medusæ are also found in deep seas, although their presence at great depths would hardly be expected. Haeckel remarks that "few animals appear less suited for deep-sea life than the medusæ, with their soft, mucilaginous, watery bodies, and their singular methods of swimming; nevertheless, a few species sink down to great depths." One of the most interesting forms adapted for deep-sea life is the *Pectis antarctica*, belonging to the family of the *Pectinidæ*. This animal is remarkable for its sucker-tentacles, which stand

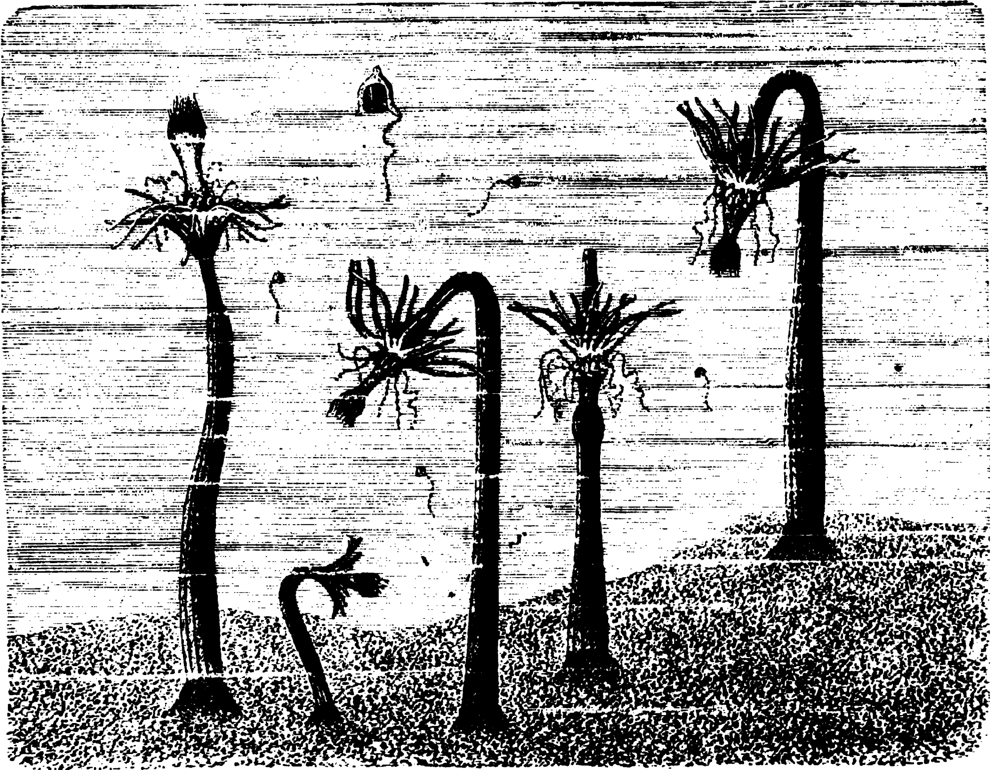


Pectis (nat. size).

in numbers round the margin of the firm cartilaginous disc (these in the illustration are represented in a contracted condition). These tentacles bear a great

resemblance to the tube-feet of the star-fishes, being very elastic and contractile, and carrying a sucker at the tip. They are used in the living state for attachment, and for creeping in the manner of a star-fish. The disc of *Pectis* is about 1½ inches in diameter.

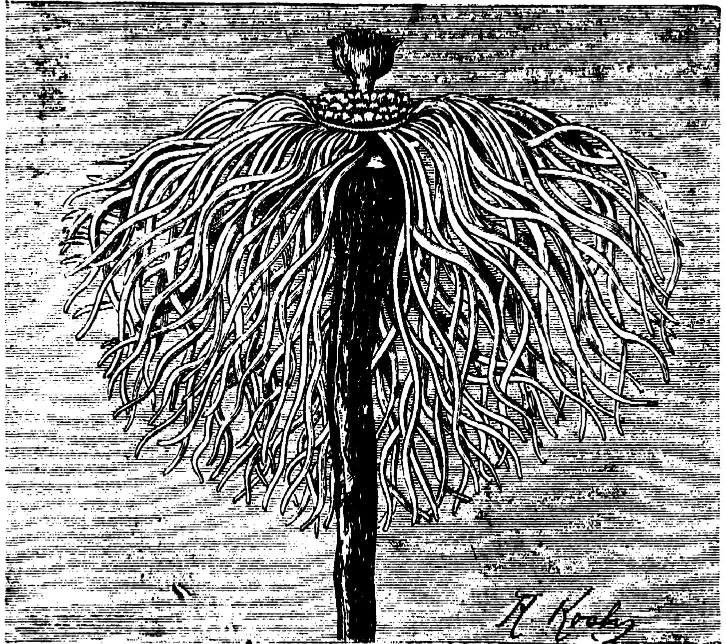
Of the forms among which the reproductive individuals swim away as jelly-fish, we may take as an example *Corymorpha nutans.* In this creature, between the five individuals grouped together in the illustration, five small creatures, each provided with a filamentous appendage, are to be seen swimming, which are the medusæ belonging to this animal. Each egg of these minute medusæ, which are no larger than in the illustration, develops into a ciliated larva, which, sinking to



Corymorpha, WITH DETACHED MEDUSÆ.

the bottom, grows into an attached *Corymorpha.* The illustration shows these animals, which in the polyp form are always single, of the natural size. Unlike most animals of this sort, they do not attach themselves to seaweed or stones, but live on fine sand, into which they sink the posterior end of the stem. Numerous thread-like appendages of this buried part penetrate the sand in all directions, thus firmly attaching the animal. The mouth at the anterior end is encircled by tentacles, a second circle of tentacles surrounding the widened part of the body which contains the stomach. Immediately above this latter circle, the buds stand in clusters; in summer they are found in all stages of development, and even while attached to their stalks assume the complete structure of a medusa. They move their umbrellas actively, break loose, and thus complete the circle of develop-

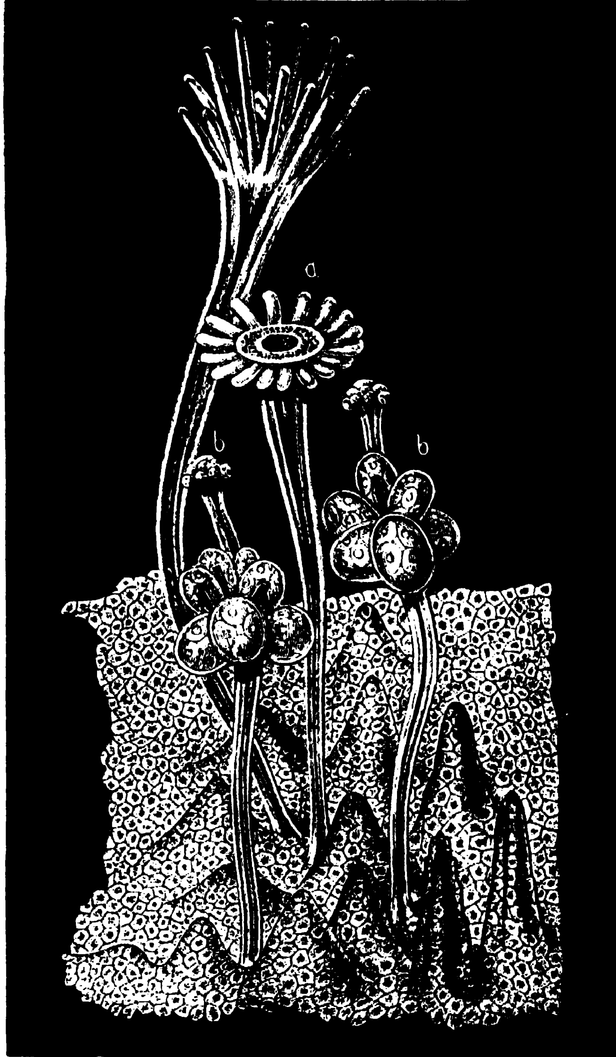
ment or alternation of generations. *Bougainvillea ramosa* is another form in which, owing to the stock being branched, the division of labour is even more clearly seen; some of the individuals are feeding and some are reproductive, these latter turning into swimming-bells, and breaking loose. Both these forms are small, as indeed are the great majority of the hydroid stocks, but whole forests of hydroid-polyp stocks may be seen on the reefs in the Pelew Islands, almost as tall as a man, and with roots three or four inches in diameter. A bather, entering such a forest, is terribly stung, the pain lasting for hours. A solitary form (*Monocaulus imperator*)—the upper portion of which is here figured—nearly related to *Corymorpha*, and found in the Northern Pacific, attains still larger proportions. These animals, brought up during the *Challenger* expedition from a great depth, were more than two yards in length, with a proportionate diameter.



Monocaulus, UPPER THIRD (much reduced).

As examples of stocks of which the reproductive individuals do not swim away as jelly-fish, we may select the pretty, feathered, plant-like creatures found along the sea-shore, which are often thought to be plants but are really animal colonies, well-known types being *Sertularia* and *Plumularia*. In these cases, in addition to the nutritive individuals, there are the egg-bearing individuals which never turn into free-swimming medusæ. In saying this, it must be left undecided whether these colonies are degenerate, that is, were once capable of producing medusæ, but have now lost the power; or whether they are in a lower stage of development, above which they have never risen. One small form which is not branched and feathered is *Hydractinia echinata*, found in the North Sea and on the English and Norwegian coasts, where it attaches itself to gastropod shells, inhabited by hermit-crabs. The polyp probably profits by changes of place for feeding, or else for some other reason adapts itself to the restless life of the crab. The part of the stock common to all the individuals is the skin-like portion which adheres to the surface of the shell or other object to which it is attached. This skin is raised up into spiny prominences, as shown in the figure on p. 488. A horny layer occurs in this integument, similar to that of which the single tubes consist. The nutritive canals running down the stems of the polyps are continued into this membrane, promoting its life and growth. In such a stock there are never

more than two kinds of individuals; namely, the nutritive individuals, distinguished by their long tentacles, mouths, and digestive cavities; and the reproductive individuals, male or female. These latter have no mouths, and are supplied with food through the system of canals running to them from the nutritive individuals. These reproductive individuals, instead of tentacles, carry at their tips a circle of stinging-batteries for the protection of their eggs, which are enclosed in capsules clustered together round the stalk a little way below the tips. The ciliated larvæ emerging from the eggs swim away, and eventually become attached and found new colonies. The egg-capsules in no way recall medusæ, but all medusæ which pass through a polyp-like intermediate stage also pass through the simple capsule stage.



GROUP OF A FEMALE STOCK OF *Hydractinia echinata.*
a, Nutritive individuals; *b*, Female individuals. (Enlarged.)

Two more of the Hydroid stocks are worth mention, since they secrete masses of carbonate of lime out of which the animals protrude like corals, which indeed they were thought to be. This error was made because only the massive skeletons of the Hydrocorallia—as they are called—and not the living animals were known. Instead of the horny, often delicately branching integumentary skeleton usually found in the Hydroid polyp stock, that of the Hydrocorallia contains ninety-seven per cent. of carbonate of lime, and forms rough, solid-looking masses, with lobed processes or bosses like those figured on p. 490, or else (*Stylasteridæ*) branches, like the precious coral of commerce. The whole surface can be seen even with the naked eye, but still better with a lens, to be covered with small pore-like apertures. Closer examination shows that these are of two sizes, a larger central pore being surrounded by an irregular circle of from five to eight smaller ones. The mass of the colony is traversed by an irregular system of numerous branching canals of different sizes. In vertical section, indistinct layers can be seen running almost parallel with the outer surface.

These form the floors of the polyp-cavities. Only in the outermost layer of the stock is there life, the inner mass being composed of dead skeleton. In this living layer there is a close network of soft branching tubes, from which rise the small polyps, the bases of which are connected together by this network. The polyps lie in cup-like depressions, and, when undisturbed, project outward through the pores, retreating instantly at the slightest disturbance. The polyps, like the pores, are of two sorts. Those inhabiting the larger pores are short and thick, with four short tentacles, resembling stalked globules, surrounding a comparatively spacious mouth. The polyps protruding from the more numerous smaller pores, which surround the large ones, are much longer and have no mouths. Each of these ends in a simple knob, below which, at intervals, and generally alternately on one side and the other, short simple branches are given off. The central polyp remains quite still, but those which surround it are constantly in undulating motion, often bending down to the mouth of the central polyp, which they appear

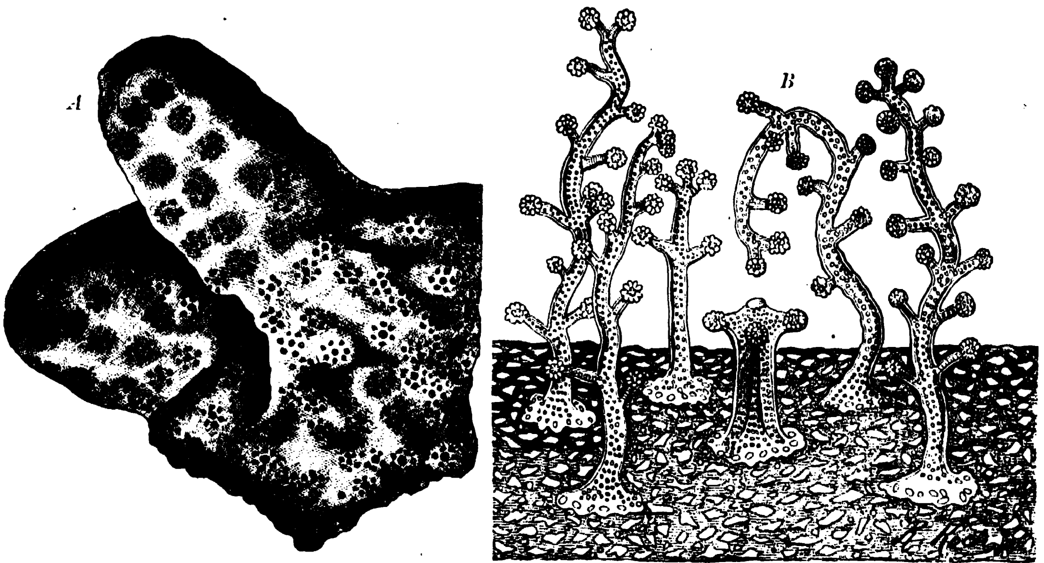


STOCK OF *Hydractinia* ON A SHELL OF THE WHELK INHABITED BY A HERMIT-CRAB (nat. size).

to be feeding. Here, again, there is division of labour in an animal colony, the larger central polyp provided with a mouth being the feeding individual, while the mouthless nutritive individuals catch the prey. The smaller polyps also probably defend the colony, being far better armed with stinging-capsules than the larger polyp. The knobs with which the tentacles end are stinging-batteries. The manner of reproduction of the Hydrocorallia—which are tropical animals and assist in building up the coral-islands—is not yet known. They grow upon rocks or dead corals, often covering the skeletons of sea-fans (*Gorgoniidæ*), and are even found in the Bermudas on old bottles thrown into the sea. In the latter case the lower side of the stock is quite smooth as if polished, and reproduces exactly the surface of the glass with all its markings.

There are two families of these Hydrocorallia, as they are called, namely, the *Milleporidæ* and the *Stylasteridæ*. They are of great interest as illustrating the marvellous adaptability of living forms. While the true corals, which are polyp-colonies somewhat differently organised from these hydropolyps, secrete great masses of solid rock, we find two small families of minute hydropolyps also

building up hard coral-stocks. This phenomenon is called convergence; two different kinds of animals, starting from different points, become adapted to similar conditions of life, and eventually come superficially to resemble one another. Just as these hydropolyps forming coral were long thought to be true corals, so many other animals have, on account of their resemblance, been classed together which are now known to belong to different groups.



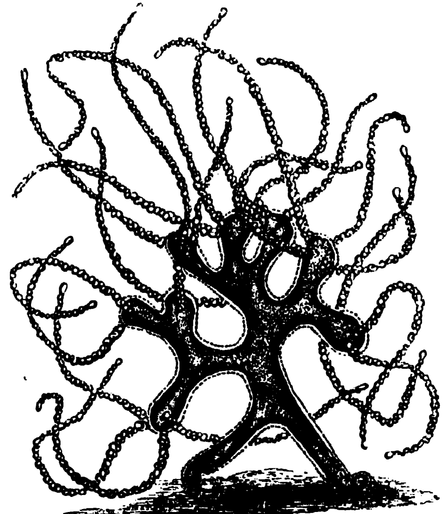
MILLEPORA.

A, Part of a stock with the polyps withdrawn (slightly magnified); *B*, Five peripheral nutritive individuals round a central feeding individual (highly magnified).

Fresh-Water Forms. Two other Hydroid polyps which live in fresh water, while all the rest are marine, deserve mention. Of these, *Cordilophora lacustris* forms branched trees from one to three inches high, rising from a network of roots attached to stones, wood, mussel-shells, etc. The whole stock—except the club-shaped heads of the individual polyps, which are provided with proboscis-like mouths and irregularly-branched thread-like arms—is covered with a delicate horny envelope. In these stocks, which are of a red-grey colour, the sexes are separate. Until the middle of the present century, the *Cordilophora* had only been met with in brackish water on the coasts of Europe and of North America. After that it appeared from time to time in the lower courses of rivers, such as the Thames, the Elbe, etc., and now it has found its way far inland both in the Old and New Worlds. It occurs in the Saale, near Halle, and is specially plentiful in the slightly brackish lake of Eisleben. In Hamburg it has in some places invaded the water-pipes supplying the city, developing in them to such a degree as actually to stop them up. This history of the migration of *Cordilophora* is instructive in helping us to understand the rise of at least a part of the fresh-water fauna. In this case, within our own experience, an animal inhabiting brackish water has in a few years become so adapted for living in fresh water as to be considered altogether a fresh-water form, without the least apparent change in its organisation. Whether a change in organisation would not

gradually take place in the course of many years is, of course, another question, which for the present is unanswerable.

In the *Hydra* we have a hydropolyp much better known and much more specially adapted to its habitat than the *Cordilophora*. These hydras, which are from one-eighth to one-third of an inch in length, form simple stocks of one or two branches, and as often as not are found single. They almost exactly resemble in form those polyps of the *Hydractinia* which are provided with a circle of tentacles. The water of stagnant pools or ponds in which water-plants are abundant will almost always yield one of the three species of the fresh-water hydra, if the water-plants be left undisturbed in a vessel. The little creatures often leave the weed and attach themselves to the sides of the vessel, where they can be examined with a lens. When undisturbed, the polyps begin to extend and spread out their six or eight tentacles like fine threads. Small creatures, coming in contact with these tentacles, remain attached to them, caught and held by the stinging-threads, whereupon the tentacle contracts, bringing the prey to the mouth, which is capable of great extension. Besides the large stinging-cells which shoot out long poisonous threads, paralysing and holding fast the small creatures that happen to come too near, the hydra also possesses a smaller kind of cells with smooth threads which are not ejected by the stimulus that leads to the ejection of the long threads. Jickeli, who closely investigated this matter, came to the conclusion that the small cells were modified for an entirely different function. However small the little crustaceans paralysed by the hydra may appear to us, relatively to the hydra they are enormous, and, on being stung, would sink heavily to the bottom. Jickeli's observations led him to think that the smaller capsules act as buoys to neutralise the action of gravitation. Indeed, when we remember how far removed tentacles are from being hands, we can understand how much more easily a victim could be got into the mouth if it floated helplessly near, than if it tended at every moment to sink like a stone. The hydra usually multiplies by means of buds which grow out of the body. The offspring often remains attached to the mother until it, in its turn, has given rise to one or two buds. Single eggs, however, develop from time to time in the body-wall beneath capsule or wart-like prominences.



HYDRA MONSTER, ARTIFICIALLY PRODUCED (5 times nat. size).

The astonishment of the naturalist Trembley, when he discovered that a hydra cut in pieces was not destroyed, but that the pieces were capable of developing into new individuals, was great. He thought that if the hydras were plants, pieces cut from them would, like young shoots, be capable of further growth. But he had, meantime, come to the conclusion that they were animals, and according to the ideas of the time it was an unheard-of thing that new individuals could grow from cut-off pieces. And thus commenced his experiments

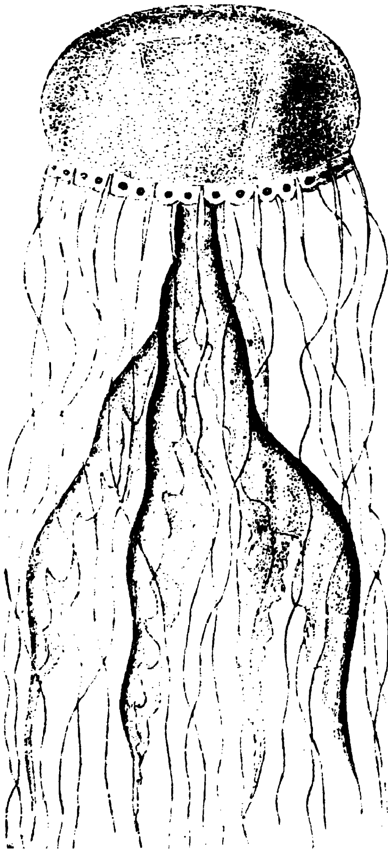
of cutting up hydras, which excited the liveliest interest among naturalists in the middle of last century.

The hydra is also remarkable on account of its capacity for regenerating lost parts of the body. Thousands of hydras have been cut up in all possible ways, grotesque monsters being produced of which drawings were made. Trembley also made attempts to turn the hydra inside out, like the finger of a glove. His first experiments of this sort with fasting animals were not successful, but he succeeded with others which had been well-fed. Animals thus treated often succeeded in returning to their natural condition.

The formation of buds was watched with care by Rösel, who did not fail to notice that the digestive cavity of the young polyps, growing out at various parts of the parent animal, even when provided with functional mouths and arms of their own, still remained in open communication with the digestive cavity of the parent.

Order Scyphomedusæ.

In the Scyphomedusæ we again have free-swimming jelly-fish, stocks developing into jelly-fish, and persistent stocks which never form jelly-fish. Whereas in all the Hydromedusæ the mouth opens directly into the stomach, in the Scyphomedusæ, and their attached and related forms, the skin round the mouth has been drawn in to form a tube which opens some way down into the stomach; the drawing-in of this mouth-tube, or œsophagus, having led to the formation of ridges on the wall of the stomach, which hold the inner end of the tube in place, as shown in the illustration of *Monoxenia*, on p. 496. Although this does not appear important, it indicates a higher specialisation.



Chrysaora (nat. size).

Taking first the free-swimming jelly-fish, the larger and more characteristic forms are distinguished by their delicate colouring. The yellow and yellowish red *Chrysaora ocellata* are seen floating past in thousands off the southern coast of Norway. The western harbours of the Baltic Sea, after continuous northerly winds, are often filled with whole banks of the blue *Aurelia aurita*, and the splendid *Rhizostoma* are constantly to be met with in the Mediterranean and Adriatic Seas. On a fine spring day they are almost always to be found on the shore, where these large, reddish blue, living hemispheres are wrecked, and soon melt away. Indeed, the bodies of all jelly-fish contain so large a proportion of water that when a tolerably large specimen is laid on blotting-paper it evaporates, leaving no other trace than its outline on the paper. In these

medusæ—which are well known to all who dwell on the coast, and range from one to seven inches in diameter—we have the most highly-developed of the simple Cœlenterates. Their body consists for the greater part of the circular umbrella, the margin of which is notched all round so as to hang down in large or small lobes. There are also, along the margin, from four to eight or more eye-like spots, and extensible filaments. At the centre of the lower side of the disc is the mouth, which in some forms lies at the end of a projecting stalk, and is almost always surrounded by several thicker folded processes for the capture of prey.



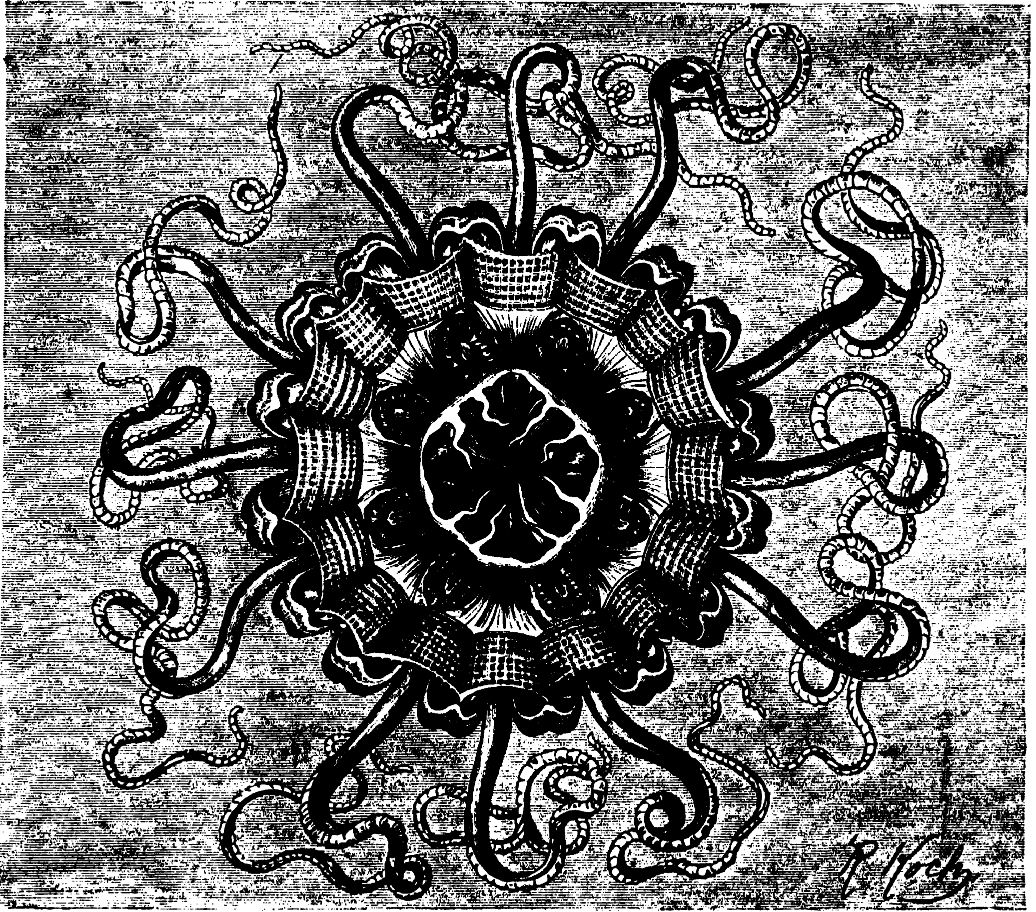
Rhizostoma.

In some cases the folded edges of these ribbon-like arms fuse together, leaving only small sucker-like apertures. Canals run from the sac-like cavity representing the stomach to the edge of the disc, where they enter a circular canal, often provided with apertures. The similarity between this apparatus of digestive canals, and the arrangement obtaining in the Ctenophora is then evident. The reproductive organs lie either in special sacs round the stomach, or merely in widenings of the canals. The surface of the skin is provided with innumerable microscopically small stinging-capsules, and, thus armed, these so-called Discomedusæ float about in the water, their bodies being but little heavier than the

water itself. Indeed, the common blue medusa (*Aurelia*) is slightly lighter than water, whereas most of these jelly-fish are somewhat heavier than that element, and sink during the pauses in their contraction.

Discomedusæ are also found in the deep sea, one form of a delicate violet, with darker tentacles, being the so-called *Periphylia mirabilis*, figured below, which was dredged from a depth of over six thousand feet during the *Challenger* expedition off the coast of New Zealand.

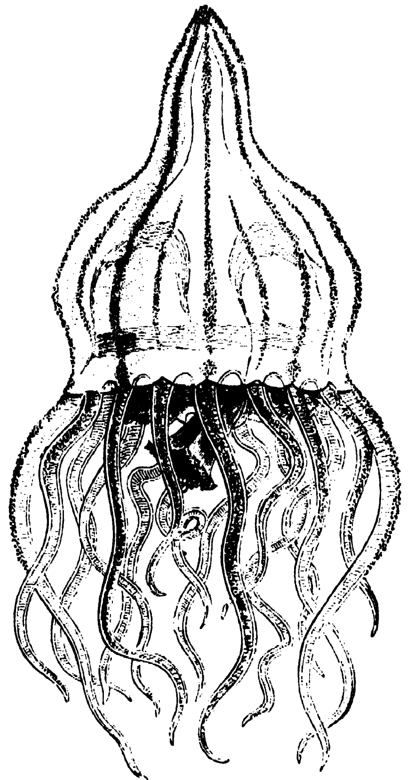
These beautiful quiet creatures, themselves apparently so harmless, are not



Periphylia ($\frac{3}{4}$ nat. size.)

exempted from the struggle for existence. Not infrequently, small Crustaceans belonging to the orders Isopoda and Amphipoda, related to the wood-lice and sandhoppers, become parasitic upon them, and many genera are attacked by a small species of fish. These fish collect in small companies under the umbrella of their prey, eating its arms, and especially their stinging-capsules, which do not appear to injure them. Although some of these splendid forms develop directly as jelly-fish from the egg, the great majority commence life as attached polyps, so that we have here again another instance of alternation of generations. The sexes are usually separate, and from the egg arises a ciliated larva, which is oval,

hollow, and somewhat flattened, recalling the shape of a locket. This is the so-called *planula*, which for a time swims about, then attaches itself firmly by the end of its body and becomes pear-shaped, the stalk of the pear being represented by the attached end; a horny envelope is then secreted over the whole surface, the mouth breaks through the free end of the central cavity, four tentacles appear, and we have a four-armed polyp or *scyphistoma*. The tentacles increase in number, and the *scyphistoma* can produce at its base a number of young polyps which again can multiply by division. At a certain period, this method of multiplication by budding of the polyps from the base ceases, and each *scyphistoma* divides up in quite a different fashion. The polyp becomes horizontally constricted in several places, until it appears like a number of cups placed one inside the other; this is called a *strobila* (pine-cone). When ready, the top cup breaks away, turns over, and swims as a young form of medusa, called an *ephyra*, which gradually acquires the shape of the perfect discomedusa. We thus have here an alternation of generations in which a sexual medusa-generation is succeeded by an asexually-reproducing polyp-generation, this again being followed by another medusa-generation.



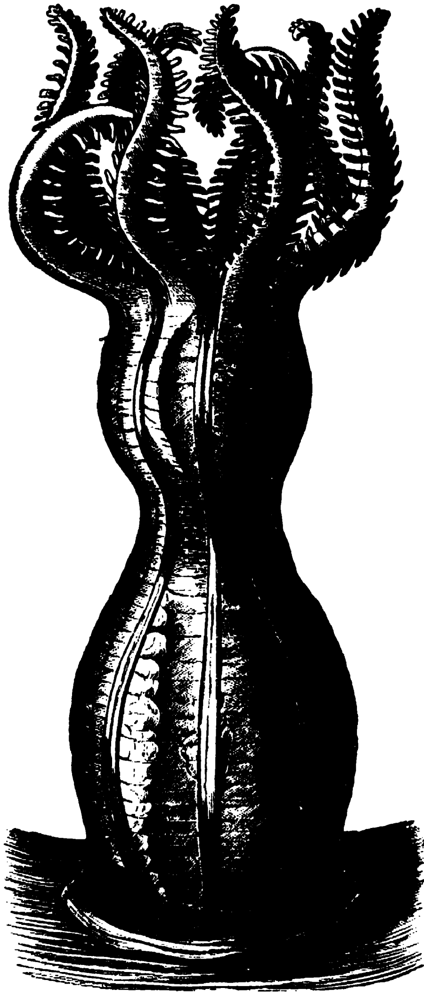
Tessera (20 times nat. size).

In relation to these, and constituting a kind of transition form connecting the Discomedusæ and the polyps, are the Calycozoa, or cup-shaped medusæ, which either swim about freely or are attached by their apices, where the firm gelatinous disc attains its greatest thickness. At the margin of the disc, these forms carry eight to sixteen arm-like processes. In the attached forms (*Lucernaria*) the ends of these processes are provided with short tentacles, occasionally broadened into discs and used for attachment, and also with stinging-capsules. The Calycozoa may leave their place of attachment and swim about for a time, with a rotatory motion, and then again settle down. *Lucernaria* has been found as deep as three thousand three hundred feet, but appears to prefer to settle in shallower water. The nearest relations of *Lucernaria* are the *Tesseridæ*. These creatures are small and swim about freely, having an elegant long bell-like shape. The edge of the disc is drawn out into alternately longer and shorter arms, eight to sixteen in number.

The Sea-Anemones and Corals,—Class **Anthozoa**.

We turn from the free-swimming Scyphomedusæ to the permanently fixed polyp forms, namely, the sea-anemones and corals; the latter of which leave behind them monuments compared with which the pyramids sink into insignifi-

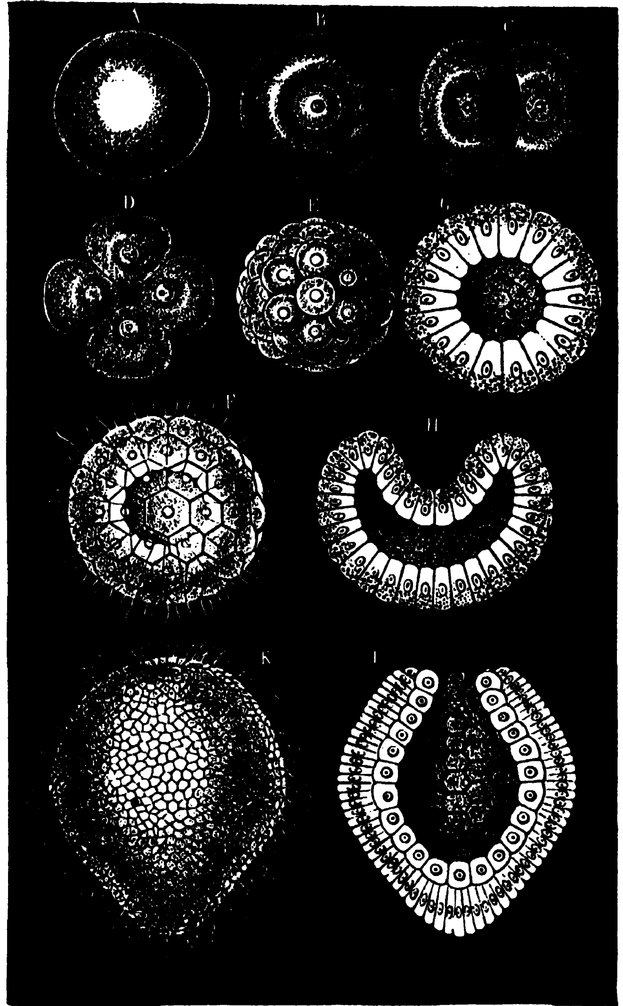
cance. Wherever these often minute animals settle, they build up great masses of rock which may form part of the solid ground of the globe. Although Aristotle and his contemporaries recognised the sea-anemones as animals, almost two thousand years elapsed before corals were considered to be related to them. In describing the development of a small coral discovered on the Arabian coast, and named *Monoxenia darwini,* Haeckel states that the polyp, which is one-eighth of an inch long, is of strictly radiate structure, the mouth, which lies at the upper end of the cylindrical body, being surrounded by eight feathered tentacles. It is attached to some substratum by means of a flexible disc at the opposite end of the body to the mouth. It is clear that it has no hard skeleton, as the shape of its surface is changeable; and its internal structure must be shown by transverse and longitudinal sections. The development of *Monoxenia* commences with the egg repeatedly dividing into many parts (*C, D, E*). This process, which is common throughout the animal kingdom and is called egg-segmentation, in this case proceeds so simply and regularly that it ends in the production of a hollow sphere enclosed by a single layer of cells (*G*). Each cell sends out a long cilia or whip-like process (*F*) by means of which the larva turns about and swims in the body-fluid of the parent polyp. One-half of the sphere now becomes infolded into the other half (*H*), and forms what is called a *gastrula* (*I, K*). The term gastrula has taken a great place in zoology in recent years, since the Russian naturalist, Kowalevski found that many different classes of animals, in developing from the egg, passed through such a stage. Haeckel, generalising from these facts, invented his Gastrea theory, according to which all animals in which the gastrula stage occurs must have been descended from a common primitive form, Gastrea, which has, however, in its simplest form long been extinct, but of which the Cœlenterates are the closest modern representatives.



Monoxenia darwini (highly magnified).

The gastrula of *Monoxenia* is of the simplest kind, the infolding being complete, and the larva forming a sac, whose walls consist of two layers of cells, or germinal layers, an outer *ectoderm* and an inner *endoderm* (see section given in the illustration). The transition from the flat dish-shape (*H*) to the sac with a narrow mouth is at once clear, and the knowledge that all the Cœlenterates proceed from a similar larva, and that all the complications of their various systems are

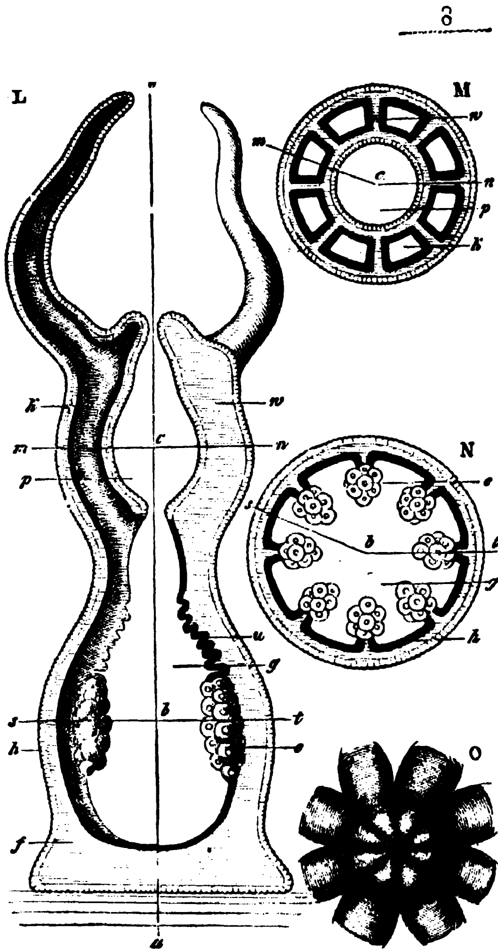
developed from such a simple gastrula, throws much light on their anatomy. During these transformations, the endoderm, whose cells multiply, continues as an uninterrupted lining to the stomach and its appendages, while the ectoderm yields the constituents of the skin. A third intermediate gelatinous layer, the *mesoglœa*, arises between the outer and inner layers; in this, muscles and connective interstitial tissues appear. The chief part of the jelly forming the great umbrella of the Discomedusæ consists of this mesoglæa. In the mesoglæa of one division of the corals the calcifications take place. These internal calcifications play, however, but a very small part in the great rock-making activities of corals as a whole, the most important calcifications being external. Returning to Haeckel's account of *Monoxenia*, although the transition from the gastrula larva to the adult animal has not been observed, there can be no doubt as to how it takes place; all the transformations having been watched in other species. The larva attaches itself with the end opposite to the mouth, the cilia disappear, and after the mouth-tube (*p*) has been formed by the folding in of the anterior end along the longitudinal axis of the body (*L*, *o*, *a*), and has thus become marked off from the stomach (*g*), the eight hollow tentacles rise round the mouth as outgrowths of the body-cavity, or as direct continuations of the stomach. Like all other corals, *Monoxenia* periodically multiplies by means of eggs which arise either in the walls of the radiating stomach partitions (or septa), or on their free edges, and have to be ejected through the mouth, as development does not in this case take place within the digestive cavity of the parent polyp. As a rule, the polyps are either male or female, but in stock-forming species individuals of the two sexes may be mixed. Hermaphrodite individuals are less frequent.



STAGES IN DEVELOPMENT OF *Monoxenia darwini* (highly magnified).

Monoxenia may be taken as the simplest type of the regularly radiate polyps; in all radiate animals the different organs being repeated in regular rings round

the central axis. *Monoxenia* and similar animals are considered simple, because the repeated organs develop similarly and simultaneously, and are comparatively few in number. The mouth, too, is circular. In many other polyps, however, the regularly radiate type is slightly departed from; the mouth, instead of being round, forming a long slit, while there is a tendency for the originally radiate animal to become bilateral. From this account of a simple polyp, it is easy to understand what kind of animal it is which makes coral; and our readers, if they have not already done so, will give up speaking of "*insects* building up the coral-reefs." It is, however, by no means all such polyps that form coral, nor do those which form it produce it always in the same way. Numbers of polyps, such as the beautiful sea-anemones, never produce any hard substance, but remain soft and delicate, though dangerous, at least to small animals, because of their stinging-cells. Many of these soft sea-anemones are highly specialised creatures, as may be seen from the coloured Plate; but those which secrete coral are generally simpler, and smaller, and grow in vast colonies. It is the accumulation of all their little contributions of coral which, in the process of time, build up islands or even continents. In regarding coral animals as reef-builders, we may leave out of account, as unimportant, those which form hard spicules within their bodies, and consider only those which perform most of the work. Imagine a crowd of small animals like sea-anemones fixed to a rock, each one secreting a layer of carbonate of lime between itself and the rock, and this layer becoming thicker and thicker till each polyp rises on a little pedestal. There is probably a race between them, as there is among trees in a forest, which shall reach the highest to get most of the food as it passes by on the currents in the water. Now, it is obvious that a crowded colony of polyps like this would in a short time add a thick layer of solid carbonate of lime to the rock on which they first settled, and this is, in brief, the principle of reef-building. As a matter of fact, however, it is

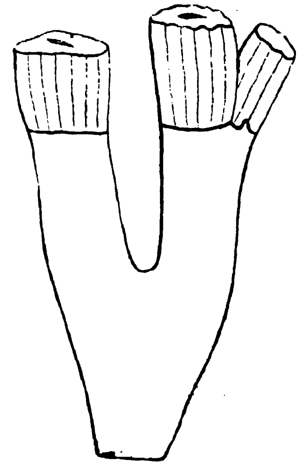


Monoxenia darwini (magnified).

L, Longitudinal section, on the left, through one of the interseptal cavities, on the right through one of the partition walls; *M*, Transverse section through the line *m n*; *N*, Transverse section through the line *s b t*; *O*, The eight-lipped mouth-aperture, with the bases of the arms; *a b c o*, Principal axis; *p*, Pharyngeal cavity; *g*, Digestive cavity; *k*, Divisions of the digestive cavity; *w*, Radial septa or walls dividing up the digestive cavity; *e*, Masses of eggs; *u*, Mesenterial filaments; *f*, Masses of muscle and connective tissue.

not quite so simple. The layer each polyp secretes is not a smooth flat disc, evenly secreted by the whole surface of its foot. Some parts of the foot secrete more than others, hence those parts rise up as spines, walls, and rings, which protrude into the body of the polyp without, however, breaking through the skin. These probably help to fasten the polyp to its pedestal, and prevent it from being swept off by strong currents. The figure on p. 505 is a good illustration of one of these plates. Each genus of corals has a pattern of its own, each one perfect and beautiful in its way, and it is frequently a puzzle to discover how it is made. When a crowd of polyps grow in contact, their pedestals will also grow in contact and form continuous masses; this growing in contact being ensured by their ordinary method of multiplication. For a coral-polyp does not have to wait until another takes up a position beside it, but as soon as it can feed freely, it begins to bud or divide, producing a number of young polyps close around it. These also bud in their turn and are soon surrounded by young polyps, and in this way such compact colonies are formed that it is a struggle among the inner ones to avoid being suffocated. We thus have densely crowded colonies of polyps struggling upwards, each individual secreting a more or less beautiful and complicated pedestal. The pedestals are fused together in a hundred different ways, and from these different patterned pedestals, with their various ways of fusing together, are produced the almost countless different kinds of coral which together build up coral-reefs.

In a growing polyp-stock the individuals usually remain in organic connection, that is to say, each first provides for itself, and then shares its superfluity with the others, sometimes by means of a continuous reticulated system of canals running from polyp to polyp, perforating the stony substance which often separates the members of the one stock from another. The whole stock may thus be physiologically one creature with many mouths. Where, however, the secretion of the pedestal is very rapid and the budding very slow the polyps may separate, each standing at the end of a branch; the illustration of *Caulastræa* showing an example of this. It will be understood from this description that only the layer of growing polyps with their intercommunications can be spoken of as living; and as this layer rises higher and higher by secreting fresh layers of carbonate of lime, the living linings of the communicating canals are either withdrawn or die away, and all beneath the living layer is mere dead matter built up and left behind by the coral animals.



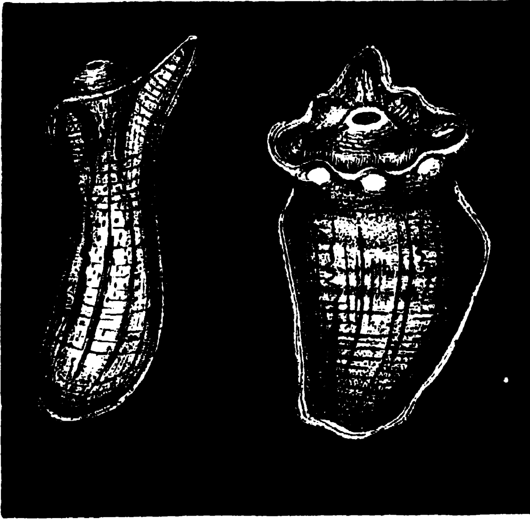
OUTLINE OF *Caulastræa* (nat. size).

Before passing to our survey of the corals themselves, two other points deserve attention. Not all corals form stocks. Some remain single, like the mushroom-corals (*Fungidæ*), which grow to a very large size with a heavy solid skeleton; and although these form new polyps by budding, the latter become detached and live as solitary individuals. Again, although coral-reefs are due to the great power of multiplying by division or budding, yet all corals, so far as is known, also at certain times produce eggs. The further development of these eggs gives rise ultimately to a

small polyp, which settles down and commences to secrete its pedestal and then to bud, thus starting a new coral-stock.

SIX-RAYED POLYPS,—Order HEXACTINIA.

This name must not be taken too strictly. It is true that it was applied in good faith, because it was believed that this order always had exactly six or some multiple of six as the number of the tentacles; but corals are tied by no such rigid rules, and all we can say is, that the number of tentacles in this order generally approximates to some multiple of six. Among the Hexactinia the sea-anemones take the first place. They spread over all seas, being especially plentiful in the temperate zones, near the coast, at depths which bring them within the reach of every observer. They are distinguished by their solitary manner of life, their size, and their vivid and usually beautiful colouring. The skin is firm and leathery, and often covered with warts. It does not secrete any calcareous skeleton either inside or outside, so that the animal is soft and capable of great contraction and changes of shape. Most sea-anemones use the basal disc for attachment, and can move from place to place by means of it, but a few species bore into sand with the posterior end of the body, or else secrete or build a sheath which they inhabit. In our coloured Plate are depicted, in their natural brilliant colours, a number of sea-anemones living in the Naples aquarium. To the left, in the foreground, are two examples, one extended and the other contracted, of the red *Actinia equina*, which varies greatly in colour. In the centre of the group, somewhat to the left, there is an extended specimen, and near the right edge a strongly contracted specimen of the lovely green *Actinia cari*. Other beautiful forms are found in the two striped anemones, *Ragactis pulchra* and *Cereactis aurantiaca*. The sun-anemone (*Heliactis bellis*), again, varies greatly in colour but is always elegant, and the same may be said of the trumpet-anemone with spotted tentacles (*Æptasia mutabilis*). In the foreground at the centre a hermit-crab is seen carrying with him his guest, the cloak-anemone (*Adamsia palliata*). A less conspicuous anemone (*Eloactis mazelii*) is provided with somewhat long cylindrical tentacles. The *Anemonia sulcata* lets its tentacles float gracefully, while the vestlet (*Cerianthus membranaceus*), of varying colour, hungrily stretches out its arms in all directions. *Cladactis costæ*, which is covered with warts, is no less voracious, but with apparent apathy allows its tentacles to droop around it.



LARVÆ OF SEA-ANEMONE (magnified).

These quiet, externally beautiful, and apparently harmless creatures are in

reality extremely voracious, devouring large pieces of flesh, and sucking down mussels and oysters. When fed in an aquarium, the long grasping tentacles greedily surround the food, such as morsels of flesh, small fish, or crabs, given to them, and convey it to the mouth; not merely are the juices sucked out, but the flesh itself is digested, only the fat being rejected. Well-fed anemones change their skin frequently, no doubt because of their quick growth. During this process, they remain closely contracted, expanding again after it is completed; the shed skin forming a loose, dirty-looking girdle round the base of the foot. Anemones only settle in places where the currents bring them the animal food they need; and are most plentiful where the current is strongest, as, for instance, at the entrance of harbours or on rocky coasts. Some species are in the habit of settling on other animals whose requirements make them frequenters of disturbed waters, hermit-crabs being especial favourites. Certain species again, such as the large yellow-and-brown-striped *Actinia effœta* (see illustration below), are indeed always found fixed upon the shells inhabited by these crabs, the one mentioned being generally found with *Pagurus striatus*, a large Mediterranean crab which inhabits whelk-shells of suitable size. Two or three of these anemones often settle on one crab, which does not seem to be at all incommoded by his burden, while the former profit in the matter of food by the wanderings of their host.

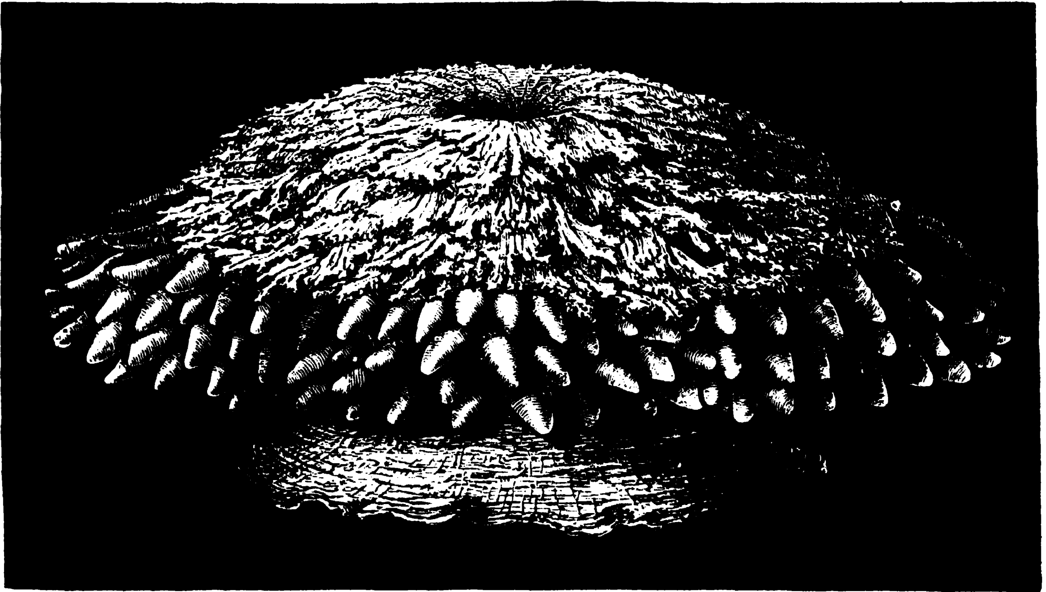


A SEA-ANEMONE, *Actinia effœta* (nat. size).

On account of the ease with which anemones are kept in captivity, their manner of reproduction has been well observed. With rare exceptions, they develop from eggs. Dalyell kept one for six years, and reared from it upwards of two hundred and seventy-six young ones. Two of these young lived for five years, producing eggs at ten or twelve months old, which hatched a couple of months later. He saw that the ciliated, infusorian-like larvæ (see illustration on p. 500) settled down on the eighth day, losing their cilia, the first tentacles appearing during the process of attachment. Young anemones often pass through their whole development within the body-cavity of the parent. Even in a free condition sea-anemones can easily be studied. Gosse has well described the many British species, and Lacaze-Duthiers has given a still more detailed account of several kinds studied in connection with their development. He gives many details of the common European *Actinia equina* found along the coasts of the English Channel in all rocky parts at low-water level. Its colour varies between scarlet, rose-red, dark red-brown, and olive-green, a distinguished characteristic being a circle of beautiful blue warts below the tentacles.

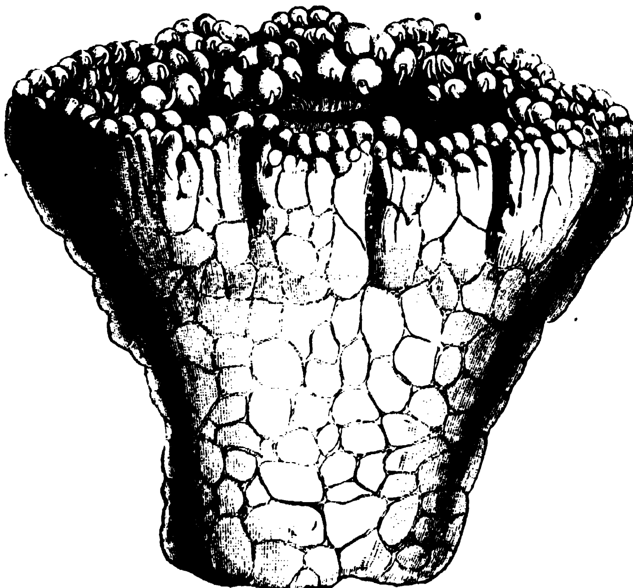
Most anemones are provided with several circles of more or less similar cylindrical tentacles, but there are some specially beautiful species which, besides tentacles of the usual shape, have, either within or outside of the circle of ordinary tentacles, lobed or leaf-like tactile and seizing organs. These belong to the family of the *Crambactinidæ*. The beautiful *Crambactis* from the Red Sea, shown in the

illustration, has, immediately round the mouth, several circles of delicate grasping tentacles, shaped like curly cabbage or endive leaves. Below these comes a circle of numerous thick arms altogether unlike the others, being rough-skinned, and of a simple spindle shape, the body itself forming a thick disc. All the tentacles of



ENDIVE-ANEMONE, *Crambactis* (somewhat less than nat. size).

the sea-anemones are hollow, with a fine aperture at the tip, through which, when the animal contracts, the water contained in the body-cavity can be expelled, but in the deep-sea forms these organs are very curiously modified. For instance, in the genus *Polysiphonia*, here illustrated, the tentacles are short and unsuited for catching and holding prey; but the aperture at the tip is large, and through it flows in water containing organic detritus which can be used as food. The allied *Sicyonis* has sixty-four wart-like tentacles with wide apertures standing in a double circle round the mouth, and in *Liponema* the body-wall is perforated by several hundred apertures leading into the digestive cavity and corresponding to the tentacles.



SHORT-TENTACLED ANEMONE, *Polysiphonia* (nat. size).

Although most members of the group arise as

single individuals from eggs, some multiply by the detachment of small pieces from the pedal disc. Fischer observed this process in the translucent anemone (*Sagartia pellucida*) on the French coast. The pieces detached on the 23rd of August had, by the 7th of September, developed into small individuals with fifteen or sixteen tentacles. Multiplication by fission seems common in several species, such as *S. ignea*, and always ends in producing single individuals. Sea-anemones sometimes, however, form stocks, but are then no longer called *Actinia* but *Zoantharia*. Such stocks are not very numerous, but some species can be found on European coasts. The genus *Zoantharia*, in which the separate individuals are united by a creeping branching root, is distinguished from *Palythoa*, in which the common stock resembles a root-like crust, on which the polyps form irregular groups of various sizes. A peculiarity common to the two genera is the incorporation of hard particles of the most different kinds—sand, sponge-spicules, pieces of shell or coral—into the body-wall in large quantities. The walls in consequence become so firm that the exact form of the polyp is retained in dried specimens. The species of *Palythoa*, although unattractive when in spirit, are of a sulphur yellow, and beautiful when alive in an extended condition. The most interesting species is *Palythoa fatua*, which is always found growing on and in one of the most curious of sponges, the Japanese glass-sponge (*Hyalonema*). Here the surface of the stalk, that is above the portion embedded in the mud, is covered with a warty crust belonging to this *Palythoa*. All the specimens of this Japanese sponge in European museums in 1860 had their stalks overgrown with the *Palythoa*, while many had their bodies also covered with another polyp which, however, settled singly and, fortunately for the sponge, did not form a sandy crust. The illustration represents a specimen of this beautiful glass rope-sponge, its body pitted all over with holes in which small Anthozoa once lived, and its stalk coated with the sandy crust of the stock-forming *Palythoa*. The former, having no skeleton, dry up entirely; no traces of them being found in dried specimens of the sponge except the holes they lived in. Unlike a parasite, the polyps do not feed upon the juices and soft-parts of the sponge, nor indeed do they share its food, but simply settle upon the sponge and feed upon the food that

PARASITIC ANEMONE (*Palythoa*) ON STALK OF GLASS-ROPE SPONGE (⅓ nat. size).
The holes on the body of the sponge are formed by anthozoans.

may chance to come within reach. It is interesting to note that a *Palythoa* closely related to the Japanese form occurs in the Adriatic, and is also attached to sponges, scarcely a single specimen of the sponge in question being found without its polyp guest. The larvæ hatched from the eggs of the *Palythoa* evidently perish unless they meet with one of these sponges; but the manner in which they find and recognise their particular host is quite unknown. Other species of *Palythoa* found on the American coast settle on the shells inhabited by hermit-crabs, covering the shell as an uninterrupted mass several lines thick, and the individual polyps rising to about an equal height above the general mass. The shell becomes disintegrated beneath this cover, and the polyp-stock then remains as the only covering to the crab. In this case there is mutual advantage, for the crab is covered and protected by the polyp-stock, while the polyp profits by its wanderings and enjoys constant change of water and new fields for food.



Palythoa axinellæ (somewhat less than nat. size).
The small dried-up polyps are seen adhering in groups to the branching sponge.

An extraordinary form, very nearly allied to *Zoantharia*, has been described under the name of *Polyparium ambulans*, and is found in the strait dividing the island of Mindanao from that of Billiton. It consists of a colony three inches long and six wide, flattened from above downward, and therefore more or less ribbon-like; and the anterior cannot be distinguished from the posterior end. The upper surface of the colony is covered with peculiar polyps shaped like chimneys, the base being much wider than the top, which carries a round aperture. Each polyp is extremely minute, and has no tentacles. They stand in irregular transverse rows of from five to eight, differing in age and therefore in size; the lower side, on which the colony rests, being beset with protuberant suckers. These also differ much in size, but stand in regular rows divided by furrows, and serve for attaching the colony, and also enable it to creep. The colony can even be seen slowly climbing up and down small stones. The polyps have no septa in the digestive cavity, the inner side being quite smooth; and the lower end of each is not closed, but communicates with a large cavity running along the whole colony, and divided at regular intervals by partitions.

True Corals. From the foregoing observations it will be seen that in the soft division of the Hexactinia, or six-rayed anemones, there are both single individuals and colonies of individuals joined together to form stocks; and there is also the same diversity in the skeleton-producing division—the corals proper, where we have both single individuals and stocks. Whereas however, in the soft division, the simple individuals are the more numerous and the colonies comparatively rare, among the corals the opposite is the case, the colony-forming types presenting almost innumerable varieties. This is not difficult to understand, since the soft anemones cannot well form complicated colonies, whereas the skeleton-forming polyps, by combining their skeletons, can build complicated structures, in order to raise themselves into more advantageous positions. We have first, then,

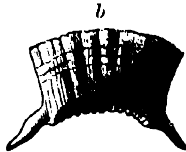
to consider those corals which do not typically form stocks, but remain at the stage of a simple sea-anemone, only with a rigid, calcareous skeleton supporting, and no doubt protecting, them in different ways. All the corals found in British seas are (with the exception of the so-called tuft-coral) single, and generally very small. As an example of a regular, circular, solitary coral, we may take *Thecocyathus cylindraceus*, the skeleton of which is shown in the illustration. The animal when expanded fills up the central depression, but when, on expelling the greater part of the watery contents of its cavity, it contracts, the whole body seems to sink into the hollow cup formed by its skeleton. In the illustration we see only the outer wall and the top of the ring of septa, which are solid vertical plates, rising up from the pedestal secreted by the foot and radiating outwards in all directions. Two other solitary corals are worth describing, as they show certain interesting specialisations. Both of them may increase by budding, that is, by the method which, in colony-forming corals, leads to the formation of stocks, if the buds remain attached to their parents. When, however, solitary corals bud, the buds fall off, and lead solitary lives like their parents.

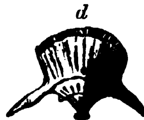


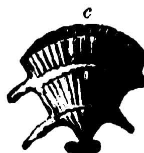
A SIMPLE CORAL, *Thecocyathus* (nat. size).

Most of the numerous species of the scarlet crisp-corals (*Flabellum*) are individuals, and are characterised by the slit-like form of the mouth. At *a* in the illustration the living animal is seen from above, while *b* shows a side view of the skeleton, which is attached. It resembles a pair of fans fastened along their edges; and just inside the outer edges of the fans is the row of tentacles. The whole animal is as if the upper end of a circular polyp had been squeezed, so that the mouth-area, instead of being round formed a long oval (*a*). An interesting case of budding occurs in these corals, the buds falling off. In the illustration, *c* shows the bud growing out at the top of an individual like *b*. In this budding condition the coral might pass for a different species of *Flabellum*. The bud, however, ultimately falls off (*d*), but instead of becoming attached, is swept by the waves into some rocky fissure, where it spends the rest of its life. Besides the fact that it remains unattached, this bud differs from its attached parent in a far more important respect. It can produce eggs, which the fixed coral can not do, so that we have here another case of alternation of generations. Out of the egg comes an attached form, which buds and produces the free unattached form, which again produces eggs, and so on. The predominating colour of this species is a beautifully intense and yet transparent red, the mouth-disc having almost always broad bands of darker red, most marked in the paler specimens.







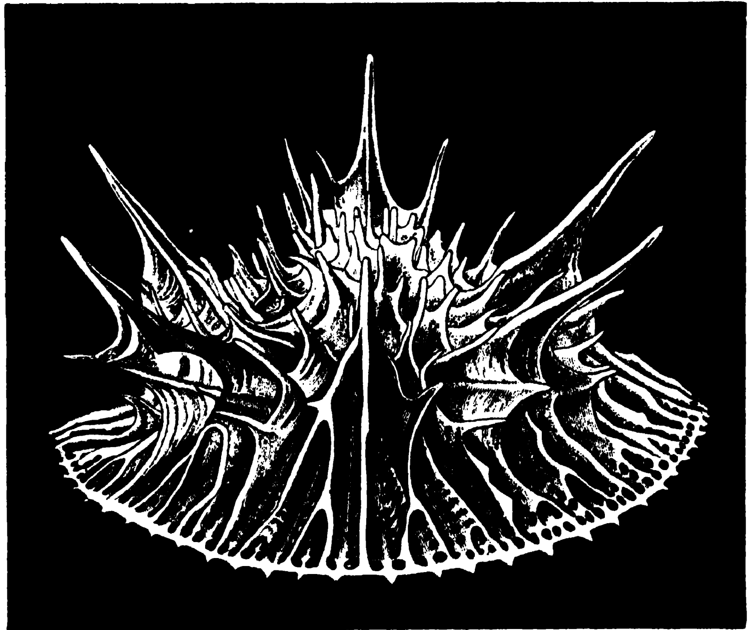


SCARLET CRISP-CORAL, *Flabellum* (nat. size.)

The mushroom-corals (*Fungiidæ*) are another remarkable group of solitary forms, taking their name from their resemblance to the head of an expanded mushroom turned upside down. Turning to the figure of *Thecocyathus* (on p. 505), and imagining the circular wall pulled down all round, and drawing down the septa so that they radiate outwards, some idea of a *Fungia* may be obtained. Their skeletons are remarkable objects, which no one, at first sight, would in any way connect with a sea-anemone. Although the mushroom-corals are considered to be individuals, reproducing themselves by means of eggs, both budding and division into halves occur exceptionally; in the former case the buds sooner or later becoming detached. In some there is an alternation of generations, leading to the formation of compound stocks. In the illustrated form true mushroom-corals are produced at the ends of the branches; at *a* one has become detached, and the others are in different stages, the youngest being nearly cylindrical, like a typical polyp, whereas the older ones spread out like a typical *Fungia*. When a bud has fallen off, the stem seems capable of developing another. This is the asexual generation, reproduction by eggs being the sexual generation. Lastly, certain solitary corals have recently been discovered in the deep sea, where, on account of the presence of carbonic acid in sufficient quantities to make itself felt, there is little lime. On this account the calcareous skeleton is generally distinguished by great delicacy. A deep-sea coral with such a delicate skeleton (*Leptopenus*), found off the east coast of South America at a depth of over a mile, is shown in the illustration. Its pedestal is formed of a delicate network with fine rays or spokes, connected together in a regular manner by transverse supports.

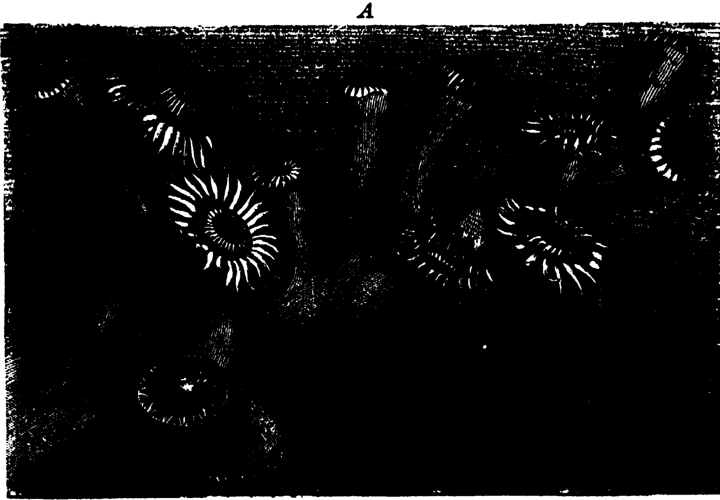


MUSHROOM-CORAL BUDDING AND FORMING A SMALL STOCK (nat. size).


A DEEP-SEA CORAL, *Leptopenus discus* (nat. size).

Plentiful as are the solitary corals, they are surpassed in number by those which form compound stocks; that is to say, in which the buds do not fall off but go on budding till coral-islands and barrier-reefs are built up. As it is impossible to give here more than a very few illustrations of the many different ways

in which the coral-stocks grow, we can only select a few types. In *Dendrophyllia*, as shown in the illustration, we have a tree-like growth; each polyp secreting a solid pedestal for itself, and living in a depression in the top. This is shown in the section *B*. Into this depression the soft animal

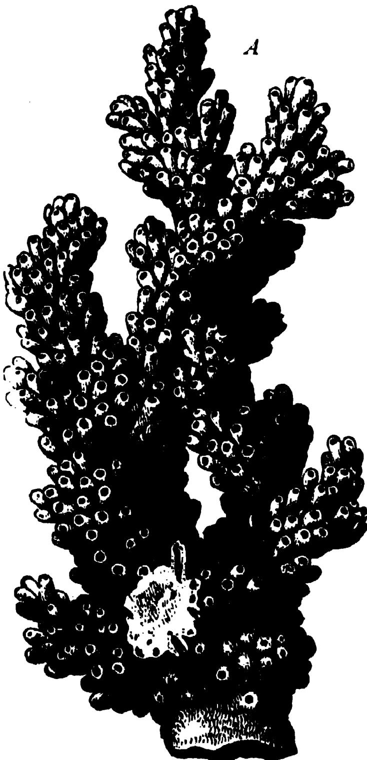


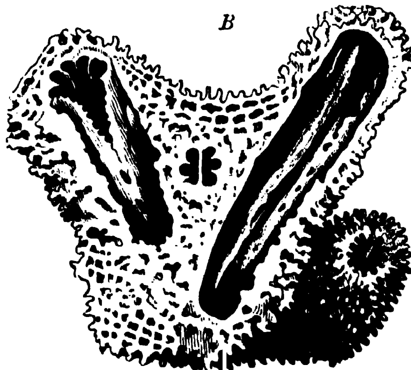


A BRANCHING CORAL, *Dendrophyllia*.
A, Terminal branch of a stock (nat. size); *B*, Longitudinal section of a single polyp (magnified).

can withdraw at the approach of danger, drawing all its tentacles (which also contract) down to *a*. The space occupied by the animal is not very roomy at the best, and it is further limited both by a great columella *d*, rising up in its interior, and by the solid septa *b* projecting into it all round. It must not be forgotten that these parts are not in the animal but outside of it, and as they are secreted they push the skin up and never penetrate into the tissues themselves. These polyps bud at intervals, the apical polyp most frequently; and the result is a simple branched stock, as seen.

A different kind of stock is developed when the polyps produce many buds, as in the madrepores. In these delicate stocks, selected polyps spring up above the rest, and their sides become covered with small buds. Space would obviously not permit all these small buds to bud again in the same manner. A few favoured ones, however, which have sufficient room next spring out and become covered again with small





A MADREPORE CORAL (*Madrepora verrucosa*).
In the section *B* the canals which connect the polyps through the stony skeleton are seen.

buds. Each bud is a living, feeding, coral-animal, surrounded by its crown of tentacles. These madrepores play no small part in building up coral-reefs, and the many different elegant forms which they assume (while keeping to their method of budding) is astounding. Some corals, again, do not form true branches, but may cover the ground like a field of corn,—a good example of this type being found in *Cladocora cæspitosa*, which inhabits the Mediterranean and Adriatic seas. Here the single individuals form somewhat long tubes, and the buds arise laterally at the lower end, then bend upward and grow alongside of the parent, without any further connection or fusion. The spaces between the different rising polyps are not filled in with secreted hard matter, but the latter grow up side by side free. The stock, therefore, is easily broken. This coral flourishes extraordinarily in many places, covering areas of over one hundred square yards, with a growth of a foot in height.

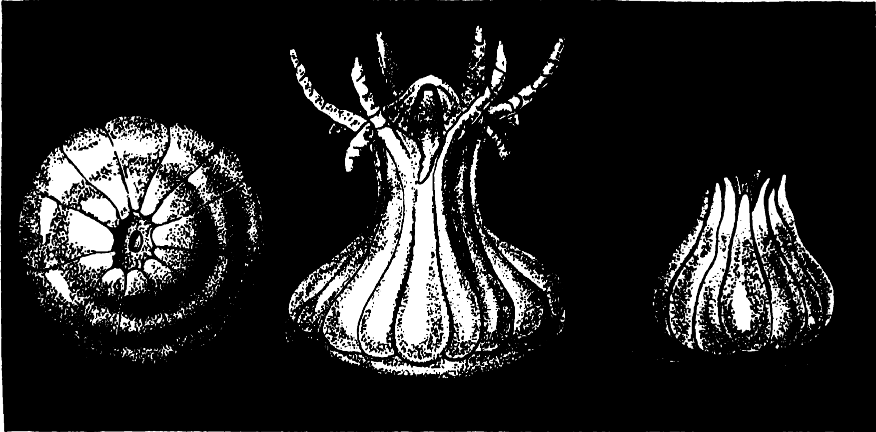
The method of growth just described is shown also by another and quite different coral, *Astroides calycularis*. As in *Cladocora*, just described, the single



A MASSIVE CORAL, *Astroides* (nat. size).

polyps, with their calcareous tubes or pedestals, are not fused together by any cementing substance. The yellowish red polyps are seen standing out a great height above their cavities, much more so than is usual in corals. The larvæ of these corals leave the egg while still in the large, chambered body-cavity of the parent, where they swim about for a time, till they escape through the mouth. They are long and worm-like, and slightly thicker at the posterior end, but may change considerably in shape. They swim about rapidly by means of their covering of cilia, the thicker end being foremost. The mouth appears at the thinner end soon after the larva leaves the body of the parent. Its free-swimming life has been known to last as long as two months; but under natural conditions it would probably be shorter. A strong sirocco had a marked effect upon the larvæ, which

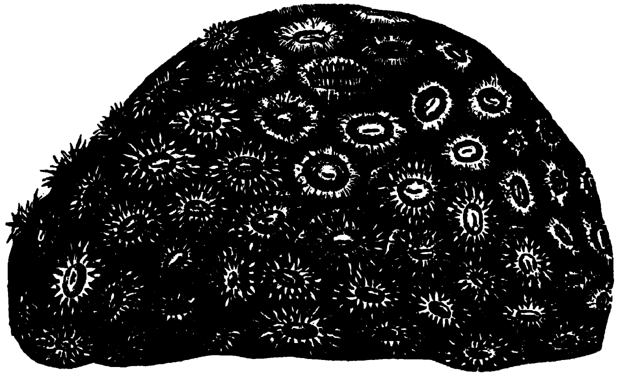
seemed to become exhausted, contracted, and became attached. The transition from the worm-like larva to the polyp takes place as in the anemones. The thicker end of the body is pressed against a hard rock, and the whole contracts into a thick, round disc; while longitudinal furrows become visible at the upper pole, where the mouth sinks deeper. At the ends of these furrows the twelve tentacles appear. The accompanying three illustrations show the stages which



DEVELOPMENTAL STAGES OF *Astroides calycularis* (magnified 24 times).

follow in rapid succession, resulting in a form almost exactly like a young sea-anemone. It has, however, already commenced to secrete its calcareous skeleton. This is not formed as a connected whole, but begins as a number of separate centres of secretion between the polyp and the substance to which it is fixed. These meet and fuse, till gradually the skeleton is produced. The polyp commences to bud, and the buds develop their skeletons, the whole together forming a stock like that shown in the illustration.

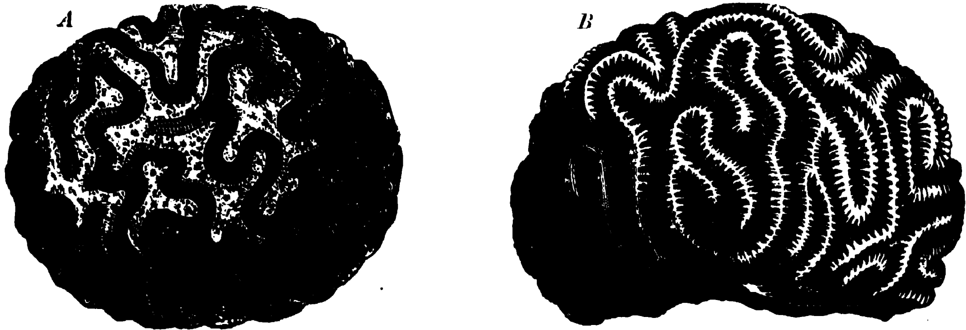
The star-corals, which are some of the principal reef-builders, do not branch, but form great solid mounds; the polyps being all cemented together, and the budding so arranged that the whole colony forms a thin, living layer or covering to the mass it and its parents have built up; all but this thin layer on the surface being dead coral. The illustration given is of *Astræa pallida*, a species which appears as a rounded mass, with flat base, and the individuals being quite distinct from one another, although their outer walls are in contact. Those on the top and to the right of the figure are represented in a contracted condition, and the rest with expanded tentacles. None of the individuals here seen are in the act of dividing; and the genus is characterised by the fact that the bud-



A STAR-CORAL, *Astræa* (½ nat. size).

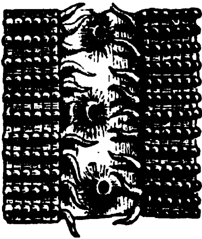
ding polyps separate from one another completely, forming so many distinct individual polyps.

In the brain-corals, or *Meandrina*, we have animals budding, but not com-



A BRAIN-CORAL.
A, Stock with the soft-parts; *B*, Skeleton. (Nat. size.)

pletely separating. No hard wall grows between the bud and its parent, although such separate the polyps less closely related. We thus get a system of valleys



THREE MOUTHS, WITH TENTACLES AND DIVIDING WALLS OF BRAIN-CORAL.

with rows of mouths, belonging to the polyps, which have budded off from one another. The valleys are bounded on each side by the hard walls separating them from similar valleys containing similar series of polyps. The three illustrations will enable the reader to understand this brief description.



A HORNY CORAL, *Antipathes arborea* (nat. size).

Horny Corals. We have hitherto described skeletonless forms, and forms secreting solid, stony skeletons; the Antipatharia have horny

skeletons, the method of secreting which will be described when we come to the horny skeletons of the next group. The polyps have only one, instead of several rows of tentacles, and in most of them the tentacles are six in number. They form compound stocks, looking like delicate shrubs, with long branches, from which the polyps project, these branches being supported by a flexible horny axis. In the Fiji Islands a stock three feet high, with a stem half an inch in thickness, has been found. The general form of the whole stock, the brown colouring, and the small, thick tentacles of the little polyps are not attractive.

THE EIGHT-RAYED POLYPS,—Order OCTACTINIA.

Although this second order of the corals contains a variety of forms, the appearance of the individual animals is more or less uniform, the number of tentacles being always eight. The tentacles are not hollow, but are usually somewhat flattened and notched round the edges like delicate leaves. These corals form stocks which are sometimes knobbed or lobed, and sometimes resemble a hand or tree with simple branches. The individuals of the stock are usually small and rise like minute white blossoms above the soft fleshy surface of the stock, which has a peculiar reddish yellow glistening appearance. The stock attaches itself by means of a stem, or else rests loosely in the sand, generally at a moderate depth. These corals secrete carbonate of lime, but in no case in the same way as do the true corals or the hydrocorals. In both these latter the solid skeleton is formed by the outer skin, while in the present group the secretion takes the form of minute calcareous particles of definite shape scattered about between the outer skin and the lining of the body-cavity. These spicules never fuse together to form solid continuous masses, but may, nevertheless, be present in sufficient quantities to give the lower part of the body a certain degree of rigidity. When fresh, the stocks show some elasticity and turgescence. When removed from the water the whole stock contracts strongly, but swells out again if placed in an aquarium, where it may live for weeks or months, although the great swelling of the lower part shows that its condition is abnormal. A tendency to form a stem is also common. The illustration on p. 512 shows an alcyonarian, as these corals are called, with its lower part modified into a stem free from individual polyps; while the next figure exhibits a representative of another family, the sea-pens (*Pennatulidæ*), which also form stocks divided into a polyp-bearing area and a stem resting on the sea-bottom. In one of the simplest forms of the sea-pens (*Veretillum*) the upper part is simply surrounded by polyps, and the lower a cylindrical stalk. A stock of this last-named type may lie for two or three consecutive weeks like a wrinkled turnip at the bottom of an aquarium, with all its activities suspended; no individual polyp appears; no food is taken in, and the circulation of water, necessary for the life of the stock, does not take place. After a time, however, the fine pores begin to take in water again, the surface becomes smoother, and gradually, as the individual polyps appear and stretch out their tentacles, the colouring of the whole stock becomes more vivid and more delicate. The stock lengthens and thickens, and the white crowns of tentacles stand out in dazzling contrast to the red of their bodies and of the

common trunk. The foot swells out like an onion and becomes transparent, curves, and sinks into the stand; and the stock, which during its period of inactivity lay prone on the ground, assumes an erect position. In these sea-pens

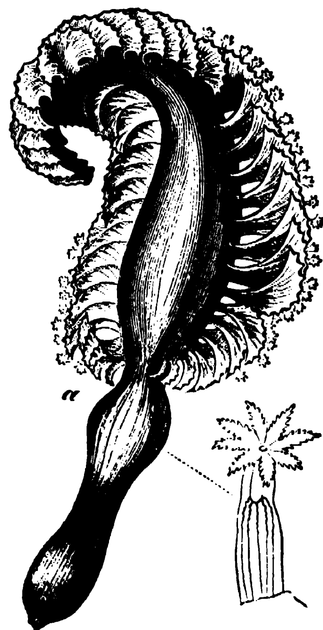


AN ALCYONARIAN CORAL, *Alcyonium* (nat. size).

the parts of the stock may be compared with the parts of a feather, the whole being bilaterally symmetrical, and the single polyps being carried on the leaf-like lateral appendages of the stem. The sexual animals, which are provided with all the organs necessary for a polyp, take in the food and reproduce themselves. The other less perfect brethren, called zooids, although more or less resembling these,

have remained at a lower stage of development, are smaller, and have neither tentacles nor reproductive organs. These zooids appear to perform only one function, namely, to pump water through the body of the stock. In this important work the higher individuals no doubt assist, as indeed in most alcyonid-stocks they alone must do the work, there being no such specialised pumping-polyps.

In addition to the small, isolated calcareous particles already mentioned within the bodies of the individual polyps, sea-pens have a further support in the form of a calcified and often flexible axis, entirely concealed in the stock and pointed at the two ends. The accompanying illustration represents *Pteroides spinosa*, in which the polyp-bearing leaves are supported by a number of calcareous rays which project at the edges as spines.

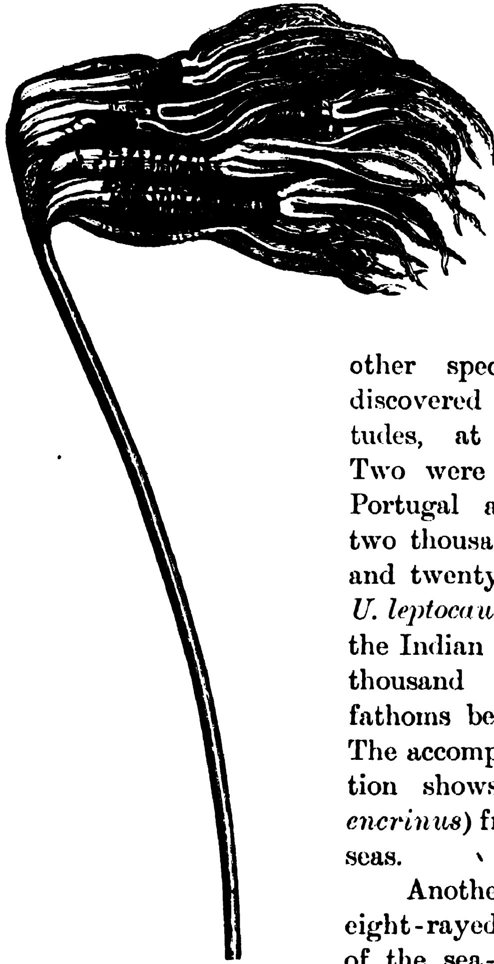


A SEA-PEN, *Pteroides spinosa* (½ nat. size).
a, A polyp (somewhat magnified).

The best known of the sea-pens is the phosphorescent *Pennatula phosphorea* of the Mediterranean and the Atlantic. In this form the capacity for giving light is not possessed by the whole surface of the stock, but only by eight band-like organs on the polyps themselves, the upper ends of which surround the mouth like papillæ, while their lower parts run down over the stomach. These bands are filled with cells containing fatty spherules, to which the phosphorescence is confined. The fact that these luminous bodies have been found in all parts of the stock is explained by the liability of the bands to be injured, the least pressure causing their contents to escape. Specimens which have been roughly treated when captured and have strongly contracted, as also those which have been kept for any length of time in small vessels and have become dropsical, are incapable of giving light. The phenomenon is only observed in freshly-caught and little-disturbed animals Very slight irritation, such as is produced by tapping on the glass of the aquarium, is enough to call forth flashes. If the animal is taken in the hand, either in or out of water, still brighter luminous spots and streaks are seen. Repeated careful experiments have revealed the fact that the streams of light follow regular courses. There are two kinds of streams; the one connected with the polyps proper, and visible on the dorsal side of the feathers, and the other connected with the zooids, and appearing on the lower side. The two streams appear at the same time, as a rule, but either the one or the other may, without any apparent reason, arise independently. It can be shown that the direction taken by the streams depends on the part to which irritation is applied.

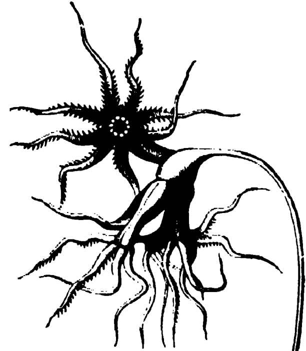
The higher forms of the sea-pens, or those which actually resemble feathers, are not found in deep water, none being recorded to exist below six hundred fathoms. Deep-sea forms have, however, been found; these being related to *Umbellula grœnlandica*, which has long been well known. As early as the middle of last century, when the presence of animal life at great depths was quite unknown, two specimens were brought up from a depth of two hundred and forty fathoms,

sixty miles from the coast of Greenland. The polyp-stocks consisted of a long, thin stem, ending in a bundle of polyps. The larger specimen was two yards long.



Umbellula thomsoni (nat. size).



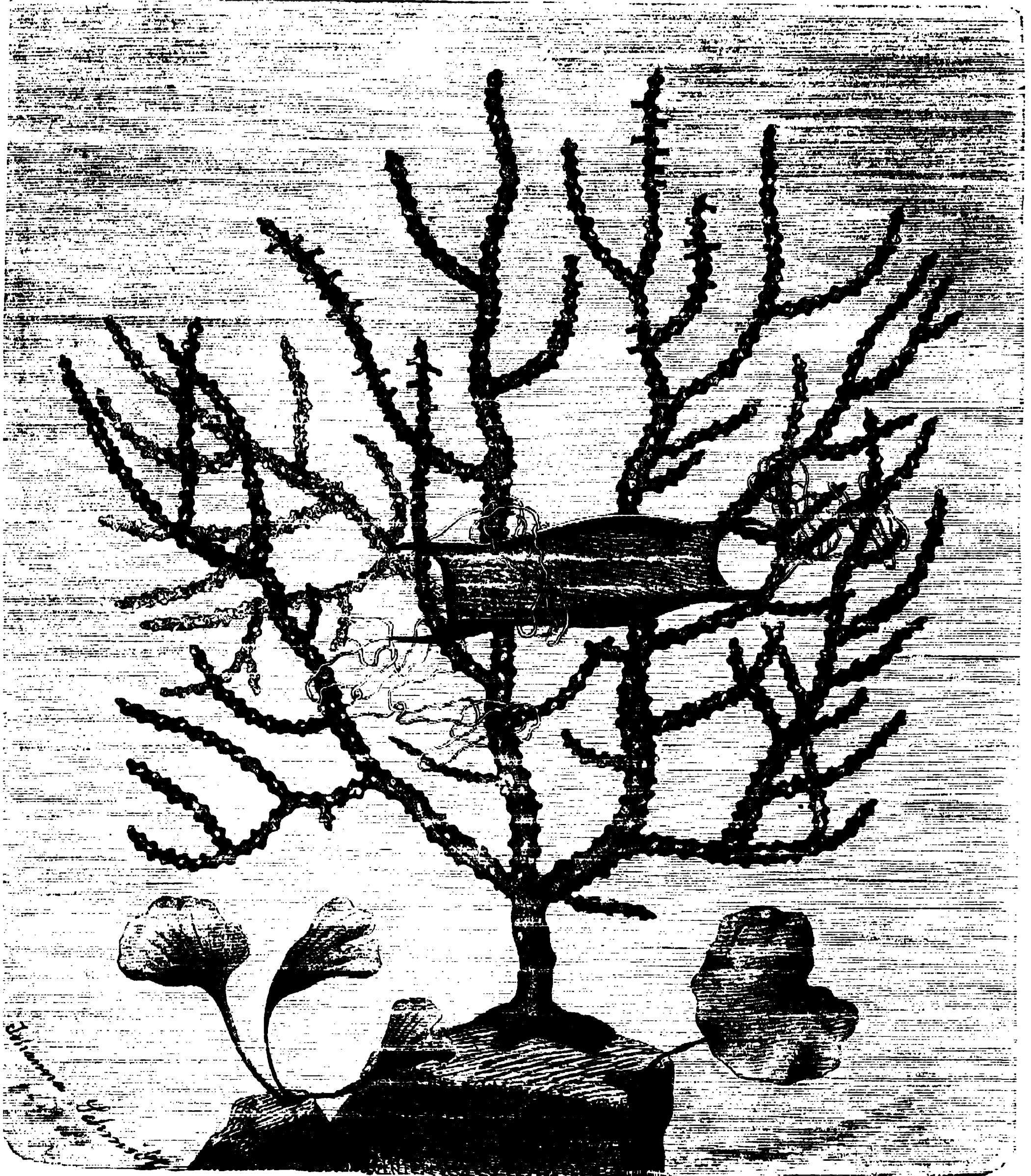


Umbellula encrinus (nat. size).

These two specimens, soon after being described, were lost, but a very similar form (*U. thomsoni*) was obtained during the *Challenger* expedition; and other species have been discovered in various latitudes, at great depths. Two were found between Portugal and Madeira, at two thousand one hundred and twenty fathoms, while *U. leptocaulis* was taken in the Indian Ocean, some two thousand five hundred fathoms below the surface. The accompanying illustration shows a species (*U. encrinus*) from the northern seas.

Another family of eight-rayed corals is that of the sea-fans, or *Gorgoniidæ*, of which the beautiful, horny, tree, and bush-like growths give no idea of the living coral. In order to gain an idea of the latter, we must picture these trees thickly covered with beautiful eight-rayed anemones. As in the case of ordinary corals, the polyps secrete the horny branches beneath their bases, and on these they rise in gracefully branching colonies. All the sea-fans are attached, and branch in the most various ways, some in all directions, others only in one plane; in some cases simple branches run out at an angle or spirally, forming fans or nets, etc. In most, the axis is horny and flexible, and they might be called horny corals, but single calcareous particles are enclosed in the axis, and its soft covering is crowded

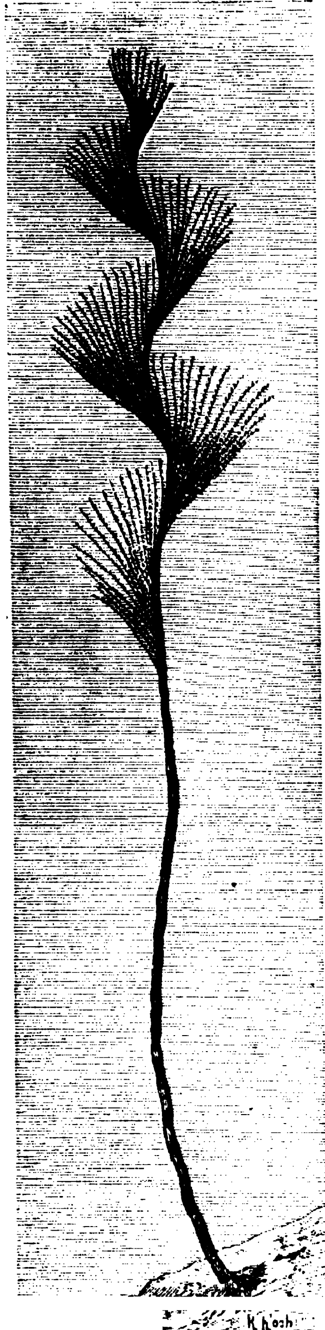
with them. The different kinds of these particles, found in different species, are of great importance in classification. One of the most common of the group is *Gorgonia verrucosa*, found in the Mediterranean, and here illustrated. A shark's egg is shown in the illustration attached to the coral by means of its



A SEA-FAN (*Gorgonia verrucosa*), WITH A SHARK'S EGG FIXED TO ITS BRANCHES (nat. size).

appendages. The soft covering of this *Gorgonia* is white. These animals occupy no very important place in the economy of nature; but several gastropods seem to attack the polyps, and brittle-stars climb up the branches in search of food. A beautiful form is *Isidigorgia*, resembling a corkscrew with a long spiral. It sends off at right angles to the principal axis, and at short intervals, delicate branches,

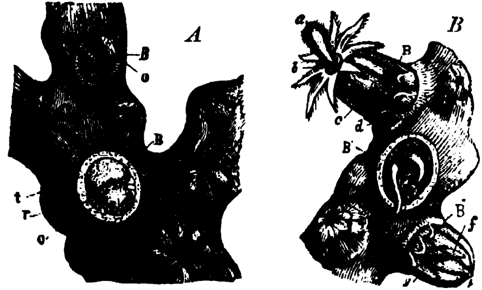
so that the whole structure looks like a spiral staircase constructed of fine cord. The accompanying illustration shows an allied form (*Streptocaulus*) of the family *Chrysogorgoniidæ*, as yet found only in the Western Atlantic. The simple or branched colonies are as thin as horsehair, and the delicate axis has a golden sheen, with a beautiful display of colours.



CORKSCREW SEA-FAN, *Streptocaulus pulcherrimus* (nat. size).

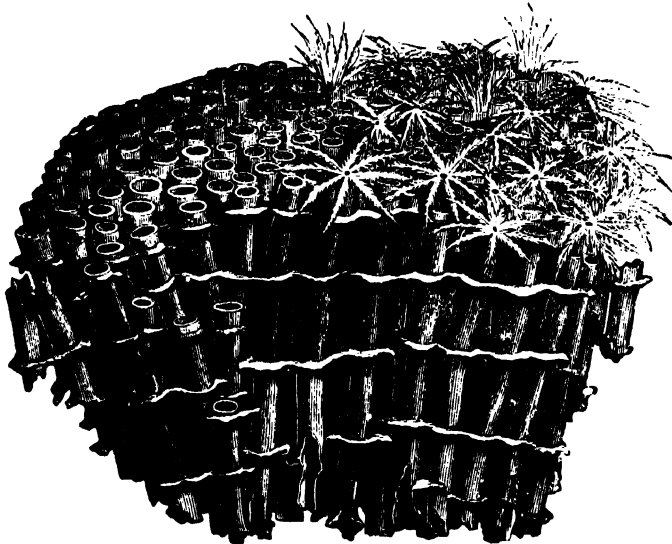
The genus *Isis*, the stock of which is partly horny and partly purely calcareous, forms a transition between the above and the red coral (*Corallium rubrum*). In the latter the axis is calcareous, and built of numerous fine layers, the microscopic structure of which is so definite that a connoisseur can detect false from real coral. The fresh axis is covered with fine longitudinal furrows, in which run the deepest of the canals connecting the polyps with one another. The stocks, as a rule, consist either purely of male or purely of female individuals, although occasionally the two sexes are found on one and the same stock, and even individual polyps which are both male and female sometimes occur. In the illustration, a slightly magnified branch of a stock is represented, with several retracted polyps and two cut open. In the upper exposed calyx (*o*), eggs are seen, while the lower (*t*) contains a large male vesicle, and at its side an egg (*o*). After hatching, the ciliated larvæ leave the egg while still within the chambered cavity of their parent (*B*). Two of the long worm-like larvæ (*f*, *g*) can be seen in the illustration through the delicate body-wall of a polyp whose tentacles are retracted, and others are visible in a cell which has been cut open. In the uppermost cell a larva (*a*) is seen in the act of passing out through the mouth (*b*). The red coral is found only in the Mediterranean and Adriatic seas; the most noted coral-fisheries being carried on off the Algerian and Tunisian coasts, at depths of forty to one hundred fathoms. The coral obtained in these fisheries varies greatly in value. The price of the broken pieces, often perforated by worms and sponges, is from five to twenty francs the kilogramme (2 lbs.); good coral fetches from forty-five to seventy francs, while choice thick coral, especially the rosy red kind, is bought at from four hundred to five hundred francs the kilogramme. Such pieces as are black, either superficially or throughout their whole thickness, are sold separately at from twelve to fifteen francs the kilogramme; these are not of a different species, but, having long been covered with mud, have changed colour as a result of chemical changes. The coral is made into articles of ornament both in Paris and Marseilles, but the chief industries are in Naples, Leghorn, and Genoa.

We conclude our description of these eight-rayed corals with the organ-pipe corals (*Tubiporidæ*), a family consisting of the one genus *Tubipora*. the members of which are neither numerous nor varied. The individuals resemble in form, in the number of their delicate tentacles and in their soft anterior body, the other living members of the order. In the structure of their skeleton they are, however, unique among extant corals, and recall certain extinct forms. Each individual secretes a smooth-walled tube, without calcification of the vertical septa. These tubes, which, like the pipes of an organ, stand almost parallel, are united to form a stock by means of transverse platforms. These latter do not, however, correspond with the inner transverse partitions (*tabulæ*), by means of which the upper living part of the tube is from time to time cut off from the dead part below. The transverse platforms are neither regularly parallel nor continuous; nevertheless they do indicate in a general way stages of growth. They are very richly provided with nutritive canals, and are of special importance for the whole stock, inasmuch as the young individuals bud out from their surfaces. As the longer tubes grow, the intervals between them increase, and as soon as there is room enough for a new polyp, one buds out from the platform. Division of the individuals or formation of buds from the tubes themselves does not take place in this family.

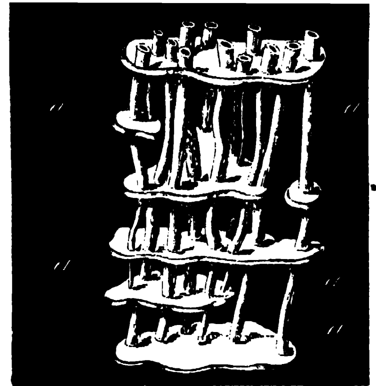


RED CORAL.

Part of a stock with retracted polyps, two have been opened (magnified); *B*, With polyps more or less extended; a larva (*a*) seen in the act of emerging through the mouth of the uppermost polyp.



ORGAN-PIPE CORAL, *Tubipora* (nat. size).



STRUCTURE OF ORGAN-PIPE CORAL.

a, Starting points of new individuals (nat. size.)

Coral-Reefs and Islands. Having described a few typical corals, and explained their general structure and characters, some mention must be made of the importance of these creatures in the economy of nature. Whereas most forms of

animal life, in passing at death into their elementary constituents, leave no visible traces of their existence, the corals, or at least the numerous reef-making forms, build monuments which last for hundreds of thousands of years, and may be said to attain their greatest importance in the influence they exercise upon the life and development of the human race. Professor Haeckel has described the magical effect of a first sight of a shallow coral-reef, enjoyed by him on the coasts of the Red Sea, where a long bank of coral runs parallel to the shore. The waves break upon these barrier-reefs, the uneven edges of which lie just below the surface of the water, and their position is thus clearly marked by the line of surf produced. The outer side of the reef, which is exposed to the full force of the waves, descends steeply, but the inner side, washed by comparatively quiet water, slopes gently down; the canal formed between the reef and the coast being as a rule so shallow and calm that the full splendour of the garden of corals at its bottom can be seen through the limpid water.

All reef-forming corals inhabit waters which in winter do not sink below a temperature of 68° F., the maximum summer heat in the Pacific Ocean being 86°. Two lines to the north and the south of the Equator, which would connect points where the winter-temperature does not sink below 68°, waving in and out according to the currents, would enclose the zone of the reef-forming corals. Most of the stock-forming corals described above live exclusively within these limits of temperature, a fact that explains their rare occurrence in the Mediterranean, which is so favourable to other forms of animal life. The richest coral regions lie in the middle hottest zone, that is between 15° and 18° north and south of the Equator, where the temperature does not fall below 72° F. The Fiji Islands fall within this region, and possess reefs extraordinarily rich in corals. The star-corals and brain-corals there reach their greatest development, while the madrepores are found as bushes, cups, or leaves, the latter often attaining a breadth of over six feet. In the Sandwich Islands, which lie outside of the hottest zone, the corals are less luxuriant and varied. The genera of corals found in the Indian Ocean and the Red Sea, as well as on the coast of Zanzibar, are essentially the same as those in the Pacific. The corals of the Gulf of Panama, although not in the hottest zone, have the character of the Pacific corals, and are different from those of the West Indies.

When the two Fosters and Cook discovered the coral islands of the South Sea, they were of opinion that the minute creatures to which these owe their origin began to build at unfathomable depths, gradually bringing their structures up to the surface of the water. They thus thought that the same species were able to live at different depths. Recent researches have disproved this; and we now know that although many different animals live at enormous depths, all such are specially adapted to the conditions of life at those depths. Animals adapted to life at a great depth cannot exist at the surface. The number of deep-sea polyps is small, and among them there are no species forming reefs; and authorities are now agreed that reef-building corals can only live at moderate depths and within certain latitudes. One of the principal requirements is pure sea-water, some species flourishing in the canals between the reefs and in the shallower water of the lagoons, whereas others require the open sea. Corals

never flourish in impure water or on sandy or muddy coasts. They are not found at the mouths of rivers nor in excessively salt water; abnormal heating of the water of the lagoons also may cause their death. The dead portion of the stocks, and also, at times, that part which contains the living animals, suffer continually from the action of boring-worms and molluscs, while the boring-sponges cause still worse injuries. In addition to these foes, which tunnel through and help to disintegrate the skeleton of the coral-stocks, other enemies prey on the living polyps. These latter are richly provided with stinging-cells; and an unwary fish touching one with its lip is sure to be stung. Nevertheless, the greediest devourers of corals are certain fish which have acquired horny beaks like those of a parrot. These parrot-fish live by browsing on the living flowers of the coral-garden, having jaws which are untouched by their stings.

Certain tube-dwelling worms and cirripedes (*Balanus*), on the other hand, penetrate the living coral without injuring it. They attach themselves to the surface of a coral-stock on leaving the larval condition, and gradually become embedded in the growing stock. Some *Serpulidæ* also grow with the stock, their tubes reaching far into it, and their elegant crown of gills, when unfolded, adding to its beauty

The rate of growth of various corals has been investigated by Dana and others. Although Darwin doubts the statement that the copper plating of a ship in the Persian Gulf was covered in twenty months with a crust of coral two feet thick, the rapidity of their growth is proved by other observations. As early as 1830 Allen sank a number of pieces of coral in the month of December on a bank about a yard below the surface of the water on the coast of Madagascar, and found, the next July, that they had almost reached the surface and had attached themselves firmly. In Hayti a growth of three to five inches has been observed in three months. A stock of labyrinthine brain-coral was found to increase 11½ inches in diameter, and 4 inches in height in twenty years. On a ship, wrecked in 1792 and discovered in 1857, a madrepore was found which had reached a height of sixteen feet, *i.e.*, had grown on an average three inches yearly, whereas massive coral-stocks in its neighbourhood showed slower growth.

The foregoing facts as to the life of the corals themselves sink into insignificance in comparison with the results of their mode of life in the formation of coral-reefs and islands.

Coral-reefs are banks of coral-rock in the sea along the coasts of tropical countries. At high tide the reefs are usually under water, but at low tide are visible as wide, flat, naked expanses of rock, just above the level of the water, in marked contrast to the precipitous coasts of the islands they surround. At high tide the only sign of the presence of a reef is a line of breakers, which often extends for many miles at a distance from the land, a retreating wave only occasionally revealing a small portion of the rock. A small island may be surrounded by such a reef, the annexed illustration showing a typical tropical island thus encircled. On the right side the reef forms a girdle stretching round the coast, and appears like a continuation of the land. This fringing-reef is also found on the left side, but beyond it, separated by a channel, is the barrier-reef. At one point the land

is seen to dip down precipitously into deep water, and here, on account of the depth of water, the reef is wanting. The barrier-reef also is broken through at one point, forming the entrance to a harbour, such as is often found in reef-surrounded islands. Many islands are bordered by a reef which protects the land from the sea like a mole. The barrier-reef may occasionally be ten or fifteen miles from land, and enclose several high islands. Various forms of reefs are found between the two extremes presented by such a barrier-reef and the simple fringing-reef.

The channel within the reef at low tide is sometimes hardly deep enough for navigation, or else it is blocked by masses of coral which render its passage dangerous. At other times a reef encloses miles of open water, ten, twenty, or forty fathoms deep, but not free from hidden sources of danger; masses of living coral, from a few square feet to several square miles in extent, rising from the bottom. In the Fijis all these kinds of channel formations occur.

The extent of the reefs, which include scattered banks and masses far below



ISLAND WITH FRINGING- AND BARRIER-REEFS.

the surface of the water, varies greatly. On some coasts there are merely scattered groups or mounds of coral-rock, the tips of which project as rocks; while, on the other hand, to the west of the Fijis there is an area covered with reef of about three thousand square miles. Other reefs are one hundred or one hundred and fifty miles long, and the Australian barrier-reef attains a length of one thousand two hundred and fifty miles.

Passing from such a tropical island girt with coral-reefs, we come to what is more especially known as a coral-island proper, or atoll, which may be described as the encircling reef without any island to encircle. It surrounds a calm lake of blue water, in striking contrast to the restless ocean outside the solid circle. The ring of solid reef in this case is usually only one hundred to two hundred yards broad, and at some parts so low that the waves break over it into the lagoon. At other parts it is covered with tropical vegetation, but it rarely rises more than three to four yards above high-water mark. Seen in the distance from a ship, a coral island looks like a row of dark points, which are the tops of the cocoanut-trees first seen above the horizon. On nearer approach, the lagoon with its green border is a wonderfully beautiful sight. Outside of the reef is the heavy surf, and within the white coral strand, the thick band of verdure, and the enclosed lake with its minute islands. In colour, the water of the lagoon, where it is deep (ten to

twelve fathoms), matches the blue of the surrounding ocean, but delicate apple-green and yellow tints mingle with the blue wherever the sand or coral-rocks approach the surface. Although the girdle of reef covered with vegetation occasionally surrounds the lagoon, it is more often broken up into a ring of separate islets of various sizes; between some of which navigable channels are found, giving admittance to the lagoon.

The submarine fields of living coral spread along the coasts of the islands and the mainland. Just as the accumulated remains of the primitive forests add layer after layer to the soil, so the coral-reefs are added to by the breaking down of old corals, by the shells of bivalves and of other organisms. These fragments keep filling up the spaces between the separate living stocks, so that the level of the reef is constantly rising towards the surface. The currents and waves also take part in the building up of the reef. Masses of coral of all sizes, from great boulders to minute sand grains are broken off by the waves, and are cast upon the reefs, and then rolled about until quantities of fine detritus are produced, which, as calcareous



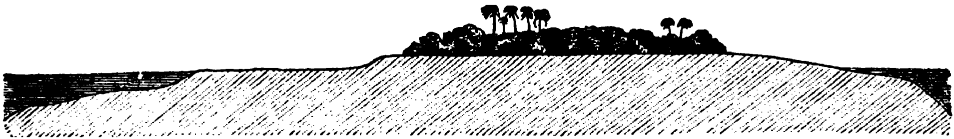
CORAL-ISLAND OR ATOLL.

mud, serves as a cement to bind the larger blocks together. A constant process of destruction goes on; some of the detritus being washed over the reef into the lagoon or canal, and some filling the spaces between the corals along the edge of the reef, while the rest remains upon the surface.

The layer of dead coral-rock forming the foundation of the reef is bordered by living coral. While this living coral is always extending the reef horizontally, the waves are piling up the dead masses vertically, till they rise above the surface of the water. Thus dry land begins to form, and by degrees islands arise well out of the reach of the waves. The ocean is thus the builder of the coral-island as it appears above the waves, the material having been supplied in the first place by the coral-animals. The moment the island is above water, plant seeds reach it from distant lands, and ere long cover it with vegetation. The accompanying section of a coral-reef shows the slope of the reef, both towards the lagoon on the right and the open ocean on the left. At *b–c* is the steep slope from shallow water to the land level on the outer side, and at *d–e* the gradual slope on the inner side. The latter slope is then continued at almost the same angle (*e–n*), the quiet water not disturbing the slow accumulation and growth of the lagoon or canal shore. On the outer side of the reef, however, a broad terrace (*a–b*), succeeds

the steep slope, and surrounds the land which has risen above the sea, this terrace being exposed at low tide.

We have still to mention some of the causes of modification in the form and growth of the coral-reefs. The presence of harbours in reefs and atolls can, as a rule, be traced to the tides and to local ocean currents. There is generally an outflow through the canals and openings in the reefs. This is apparently due to the fact that water is constantly being thrown by the larger waves over the lower portions of the reef into the canal or lagoon, and seeks either to escape as an under-current in opposition to the flood-tide, or else strengthens the ebb-tide. These and other similar disturbances of the water in the canals bring with them much coral detritus, and render the bottom altogether unsuitable for the growth of corals. Where such currents are strong, they keep the canals clean and open. The action of the oceanic currents is often increased by the fresh waters coming from the central islands, and harbours are therefore very often found at the mouths of valleys and of their small streams. The influence of the fresh water itself on the



SECTION THROUGH A CORAL-REEF.

corals is not so great as is usually assumed, chiefly because it, being lighter than salt water, flows away on the surface of the latter and hardly touches the animals which grow below the surface.

The form of the reef is again largely influenced by the form and constitution of the sea-bottom. Where deep submarine fissures occur, dipping down below the level at which the corals flourish, no reef can be formed, as also in places where firm ground alternates with sand and mud. All irregularities in the outline of a reef or an atoll, and the formation of harbours in coral islands, can thus be simply explained.

The most important point which needs elucidation is why some reefs encircle islands as a fringe extending from the shore, while others run parallel with the land, no longer touching it; others, again, forming circular lagoons with no island at all in the middle. This was the question which puzzled the first discoverers of reefs, and at one time it was supposed that instinct guided the animals in giving their structures the form best suited to withstand the force of the waves. According to another hypothesis, put forth by Steffen in 1822, the reefs represent the summits of volcanic mountains, the crater being filled by the lagoon, while the channels through the reef indicate the points at which the edge of the crater was destroyed by outbursts of lava. This superficially plausible view was disposed of by Darwin thirty years ago. He argued that the volcanic cone thus assumed must either once have stood upon dry land and then have been submerged, or else must have been formed beneath the sea. In the former case, the crater would in almost all cases have been destroyed during the gradual sinking; while the formation of craters by submarine eruptions and their subsequent elevation is hardly conceivable.

This hypothesis further requires the assumption that immense numbers of volcanoes must have arisen over a limited area, and a still more improbable supposition, that all these volcanoes rose to almost the same level, seeing that the coral animals occur only within a depth of about twenty fathoms. Craters nearly fifty miles in diameter must be assumed to have existed, and others of twenty to twenty-five miles must have been frequent. For these and other reasons, the volcanic origin of coral-reefs was rejected. It is obvious also that the same objections dispose of another hypothesis, namely, that nonvolcanic summits and banks of equal height were the foundations on which corals built.

Darwin believed that all forms of reef arise by the gradual sinking of the land they surround. This theory has been confirmed in all essential points by Dana, and recently by Langenbeck. Other authorities have, however, differed.

The condition of the reefs attached to the Fiji Islands illustrates Darwin's theory of subsidence. The Goro Reef lies close to the land along whose submarine coast it grows. The Ango reef is of the same nature, but lies further from the land, having a channel between it and the shore, and forms what is called a barrier-reef, which name denotes merely difference of position, not of kind. The barrier-reef of the island of Nanuku encloses a large stretch of sea, the islands within it being nothing else than the rocky summit of a mountain. Darwin's theory gives an explanation of these differences. If, for example, the island of Ango were very gradually to sink, two things would happen,—the island would disappear little by little, while the reef would remain at the surface of the water, that is, so long as the land did not sink faster than the corals could build. When the subsidence had gone so far that only the last mountain summit remained above water, the condition found in the island of Nanuku would be realised. Instances are also found in the Fiji islands of the intermediate stages, where only a single mountain ridge and a few isolated peaks remain above water.

It is a known fact that large countries, such as Sweden and Greenland, are in the act of sinking, and we also have direct proofs that reefs and their islands have subsided. The depth of a reef, although not directly measurable, can be approximately estimated, and must in many cases be at least three hundred yards. Since the living portion of a coral-reef cannot reach more than eighteen to twenty fathoms, such a depth of reef can only be explained by the sinking of the land on which it stands. If, instead of sinking, the land rises, the reef would be lifted out of water; raised reefs three hundred feet high being known. This enormous thickness of reef can hardly be explained without a previous subsidence, inasmuch as such a height is greater than the known depth at which corals can live. The assumption that many reefs are the consequence of simple subsidence thus appears highly probable.

The accompanying diagrammatic section (p. 524) through an island and its reef illustrates the action of gradual subsidence. The island at the water-line (*I*) has a simple fringing-reef (*f f*), a narrow rocky terrace at the level of the water, which first descends very gradually and then more steeply. Supposing the island to sink to the level (*II*), what would happen? While the land has sunk, the reef has risen, and there is a fringing-reef (*f'*) and a barrier reef (*b*), with a narrow channel (*c'*) between them. A further subsidence to level (*III*) greatly increases the width of

the channel (e''). On the one side (f''), the fringing-reef is retained, while on the other it has disappeared, a fact due to currents and other such agencies. Finally, when the water is at the level (*IV*), two rocky islands are visible in a large lagoon surrounded by the reef (b''' b'''), with two small reef-islands (i''' i''') developed on

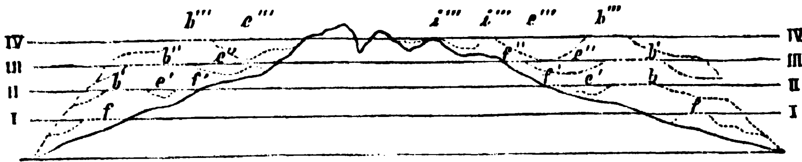
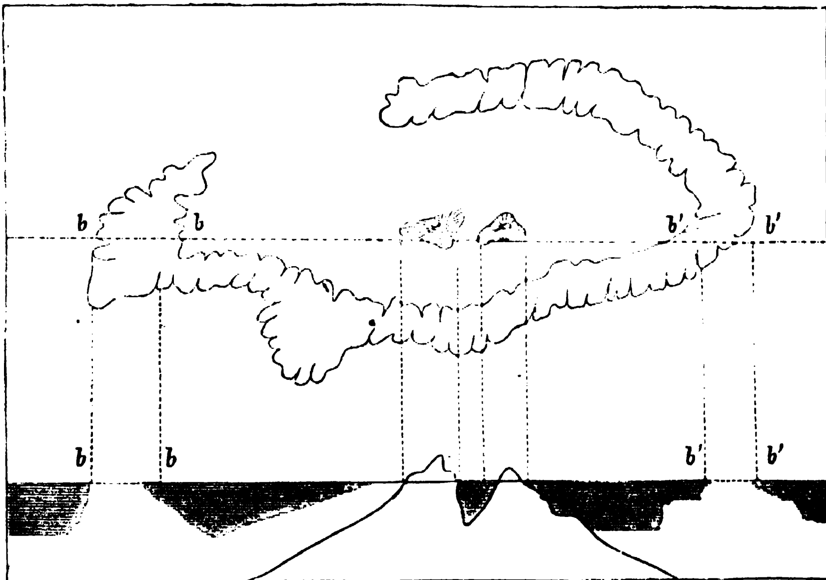


DIAGRAM EXPLAINING THEORY OF SUBSIDENCE.

mountain-peaks which have disappeared below the surface. The coral-rock has greatly increased in thickness, and almost entirely covers the former island.

Such an ideal section corresponds exactly with the reality. In the following illustration the outline of the island of Aiva, one of the Fiji group, is given. In the lagoon there are two islands resembling the summits of mountains, just as in the diagram. The exact altitudes and depths are unfortunately not known, but it will be seen how well the theory of subsidence appears to explain the conditions.

The chief objections which have been made to this theory of subsidence are

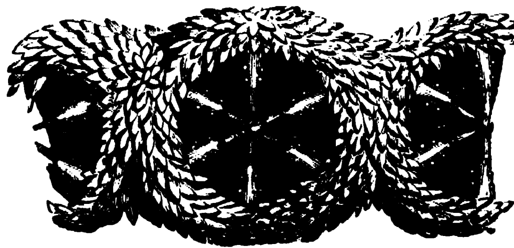


OUTLINE OF THE ISLAND OF AIVA, WITH PROJECTED SECTION.

the following. The simultaneous occurrence of atolls, barrier-reefs, and fringing-reefs in neighbouring regions does not coincide with the theory, nor does the appearance of atolls and barrier-reefs in regions in which recent elevation of the land has been proved. The discovery of extensive submarine banks of sediment formed of the calcareous portions of foraminifera, deep-sea corals, molluscs, etc., makes it possible to explain the formation of atolls and barrier-reefs without the help of subsidence, this explanation being more probable than that involving the sinking of extensive areas of land. The formation of atolls can be explained by

the better growth of the corals on the outer edges of the reef which are most exposed to the action of the surf, and the sweeping of the coral material out of the lagoon through the agency of oceanic currents, and the dissolving action of the carbonic acid contained in the sea water. The deep canals which divide the barrier-reefs from the neighbouring mainland are formed in the same way. The enormous magnitude of the reefs which the theory of subsidence demands is nowhere realised. Neither among modern reefs nor among geological formations do we find any traces of such gigantic masses of coral-rock. We are thus in face of a fascinating and important scientific problem, which still remains to be solved, a problem which was long thought to have found its solution. After Darwin's and Dana's subsidence theory had been generally for many years accepted as beautiful and completely satisfactory, we are told that it is not always applicable, and that much simpler causes suffice to explain the phenomena. It is obvious, then, that we have an ample supply of possible explanations of coral-reefs, and it is most probable that among the many scattered reefs in the world, in one case one set of factors have played the chief part, in another case a slightly different set, and further, a detailed and exhaustive study of any particular reef would probably reveal natural processes of no small importance which have not as yet been taken into account.

H. AND M. BERNARD.

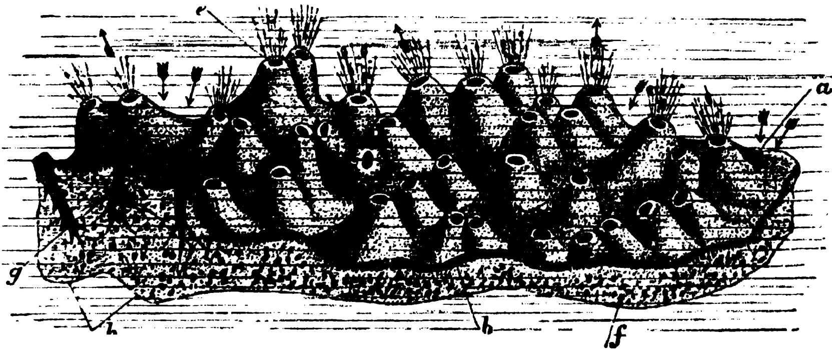


MOUTHS OF MADREPORE.

CHAPTER XV.

THE SPONGES,—Subkingdom PORIFERA.

Characteristics. THERE are about two thousand species of sponges known, which range in size from a pin's head to masses several feet in height, and vary in weight from a grain to over a hundred pounds. They assume an endless variety of shapes, such as cups, vases, spheres, tubes, branched tree-like growths, etc., but are often shapeless. When alive, they are of all colours, and their consistency may be soft and glutinous, fleshy, leathery, or stony. They are found in all seas, and in all depths from the shore margin to several miles deep, and certain species occur in fresh waters all over the globe. About three hundred species have been found round the coasts of Britain. Aristotle was the first to give a scientific account of sponges. He considered that they were either animals, or organisms transitional between plants and animals, and that they possessed sensation, since they shrank when torn from the rocks. He classified the kinds then known, and asserted that the animals often found in the cavities of sponges were intruders, and did not make the sponges; further, he distinguished the

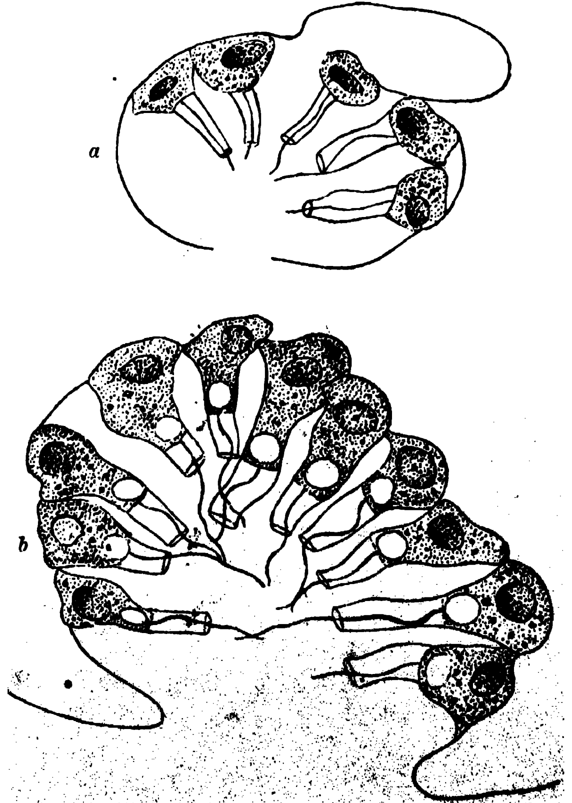


BREAD-CRUMB SPONGE, SHOWING CURRENTS ENTERING SURFACE AND LEAVING BY OSCULES.

large holes on the surface of certain species from the small ones, and thought that water was sucked in by the former.

From the time of Aristotle till 1762 little was recorded, but in that year Ellis published his observations on the bread-crumb sponge, a British species forming fleshy masses or crusts of a yellow or greenish hue. This sponge envelops the stems of seaweeds, or encrusts rocks and stones; when growing on seaweeds it forms cake-like masses with a level surface, but when encrusting rocks the surface is covered with small cones resembling miniature volcanic craters. The surface between the craters exhibits a very fine gauze-like pattern; and, by

careful inspection, groups of minute pores will be seen perforating the meshes. The large holes at the summits of the craters are termed oscules, and the small ones on the general surface, pores. Ellis, who put some specimens in a glass vessel of sea water, wrote that "We could plainly observe these little tubes to receive and pass the water to and fro"; and further, "The sponge is an animal whose mouths are so many holes or ends of branched tubes opening on its surface; with these it receives its nourishment, and by these it discharges like the polyps its excrement." Ellis's observations were erroneous in one important point. The water always passes out of the large orifices, and is not passed in by them. It is true that while the torrent is gushing out of the centre of an oscule, there is a slight passive return current at the margin. Ellis attributed the current to the contraction of the walls of the canals. He found that the current continued in the absence of any worms or crustaceans in the body of the sponges.



a, FLAGELLATED CHAMBER OF BREAD-CRUMB SPONGE, SHOWING COLLAR-CELLS; *b*, FLAGELLATED CHAMBER OF FRESH-WATER SPONGE. (Both figures 1600 diameters.)—After Vosmaer.

Our knowledge of sponges really begins in 1825 with the observations of Grant, who examined a fragment of a living branch of a branching-sponge. On bringing one of the large apertures on the side of the branch fully into view, he beheld this living fountain vomiting forth from a circular cavity a torrent of liquid matter, and hurling along in rapid succession opaque masses, which it strewed everywhere around. After many experiments, Grant convinced himself that a current flowed out of all the large orifices, and not into one and out of another. He also rubbed powdered chalk on the surface of a bread-crumb sponge, and saw particles which clogged the margins of the minute pores on the surface driven into the interior; and thereby demonstrated the passage of currents into the interior through the pores. The origin of the sponge-fountains was now traced. In all sponges currents of water pass into the body through pores, and out again by one or more ways different from those by which they entered. To ascertain the cause of the currents, it is necessary to examine the anatomy of the sponge. A thin skin, which can be peeled off, is separated from the body by numerous minute supporting pillars. On cutting into the sponge, large canals are seen passing down

from the oscules and branching into the body, and much narrower canals from the groups of pores in the skin. The channels from the pores divide up into minute lacunar spaces, or canaliculi, which finally communicate with the interior of small, spherical, flagellated chambers, whose walls are perforated by pores. Each of the chambers is the five-hundredth of an inch in diameter, and groups



SPONGES GROWING ON SEAWEED. *a, b,* Two of the Desmacidine group; *c, Spongelia.* (Nat. size.)

of them open each by one wide orifice into a common space, or canaliculus, which joins with others to form canals terminating in large oscular canals.

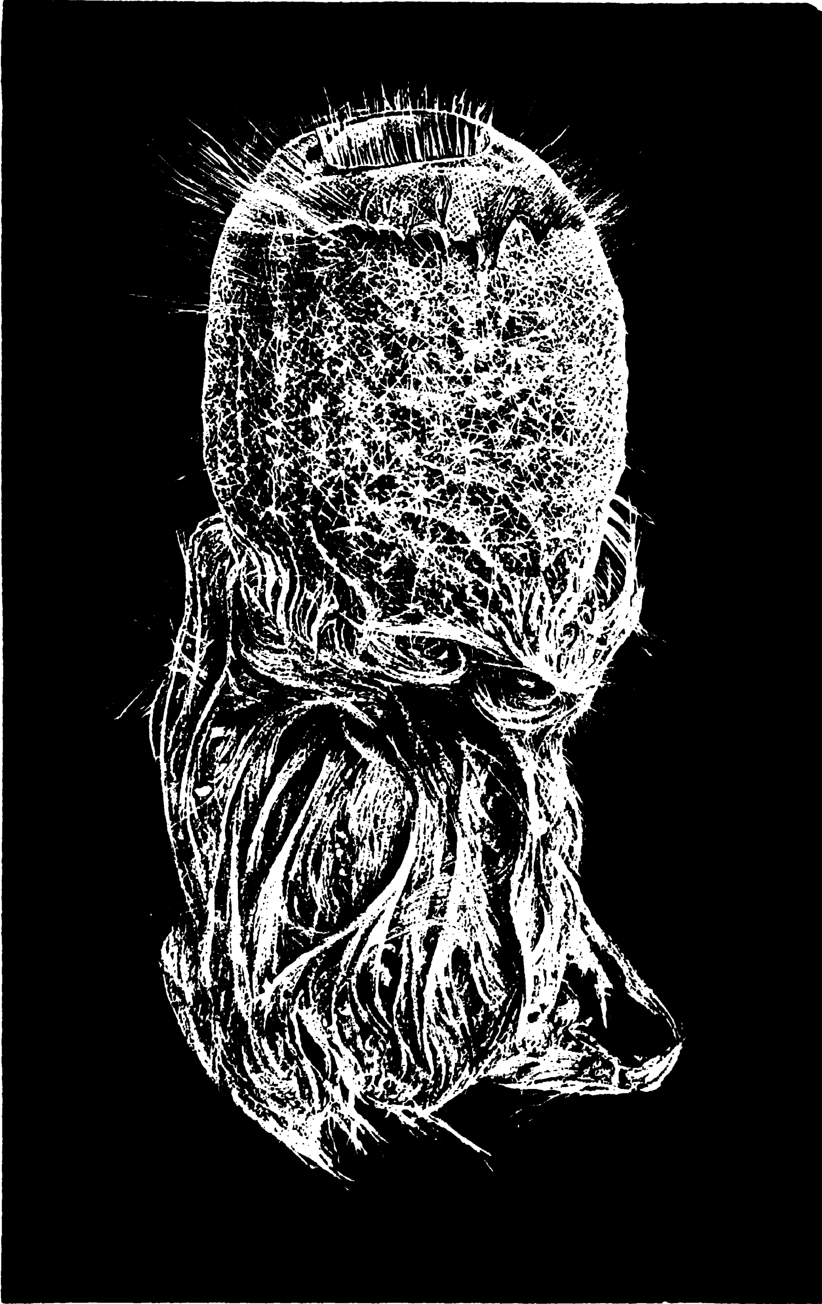
The walls of the canals are lined with flat-cells, but in the flagellated chambers the lining cells are more or less cylindrical, and each is provided at its free end with a whip-like appendage, or flagellum; and, further, the upper margin is expanded into a thin hyaline collar, so that the whip appears to rise from

the centre of a basin or funnel. The currents of water traversing the body of the sponge are kept up by the movements of the flagella of the collar-cells. The flagella beat the water in the flagellated chambers into the rootlets of the canals leading to the oscules. To replace this, water flows into the flagellated chambers from the rootlets of the canals passing down from the groups of pores in the skin. The currents entering the sponge bring in oxygenated sea-water, and minute food particles such as diatoms, infusoria, etc; the currents from the oscules contain an excess of carbonic acid, of waste products resulting from vital activity, and indigestible remains. The cells lining the canals effect the exchange of gases, and take up food-particles.

At present, too little is known as to the physiology of digestion in sponges, to permit of any definite statements being made. In some sponges, which have been fed with carmine granules and then killed, the collar-cells have been found loaded with granules; in others, again, the flat cells lining the subdermal cavities have been found gorged with the carmine. A terminal cluster of flagellated chambers in the bread-crumb sponge may be compared to a hollow mulberry, reduced to its skin but retaining its shape; each swelling represents one flagellated chamber, opening by one wide orifice into the common central space which is continued into the stalk. A grape-like cluster of mulberries would convey some idea of the arrangement of the canals, in which the hollow main stem represents the terminal oscular canal. Further, each swelling on the surface of the mulberry is perforated by several round pores, termed *prosopyles* (entrances). Another call on the reader's imagination must now be made. The openings of the infoldings on the surface are closed over by a membrane perforated by pores. Suppose the mulberry cluster to be immersed up to its stalk into a skin-bag of jelly, and the skin to be tucked in and folded so as to form channels or canals branching and diminishing in size, till they abut on to the surface of the mulberries. Again, suppose the bag to be immersed in water which, by some means, is made to enter the walls of the bag and come out at the stalk. The current will pass from the pores in the skin, then along the channels till it reaches the pores or prosopyles on the surface of the mulberries, through which it passes, and proceeds to the stalks and main stem. The system of canals from the skin pores to the prosopyles is termed incurrent, and that from the cavities of the mulberries to the orifice at the top of the stem out-current. This structure is shown in the illustration, but the representation is extremely diagrammatic. In a thin section of *Halichondria* one sees a labyrinth of in-and-out-current canals and spaces together with small flagellated chambers; of the latter, often only one or two open into an out-current space or rootlet.

The jelly mass, which in the model supports the hollow mulberry cluster and the channels from the outer skin, would of itself form an inefficient support, so we must add to it a scaffolding of rods and bars or tough horny fibres; the common bath-sponge skeleton, and the skeleton of the Venus' flower-basket are the horny and flinty scaffoldings supporting the soft tissues together with the flagellated chambers and the channels which lead to and from them in the living sponges. The fleshy or jelly substance of sponges is termed mesoderm (middle layer), because it is situated between the collar-cells, which constitute the endoderm

(inner layer), and the layer of cells on the outer surface, or ectoderm (outer layer). The usually flat cells of the ectoderm are now considered to be simply a superficial layer of mesoderm cells, and not to constitute a special



CARPENTER'S GLASS-SPONGE, *Pheronema* (nat. size).

separate layer distinct in itself. Whether this be the case or not, the terms mesoderm and ectoderm may be conveniently retained here. The ground-substance, or mesoderm, contains cells of various kinds, namely, irregularly-shaped

cells with slender branching processes, which unite with those of other cells to form a network; wandering amœboid cells, probably concerned with digestion, distribution of nutriment, and excretion; skeleton-forming cells, which secrete lime, or flint spicules, or horny fibres; contractile muscle-cells, possibly nerve-cells; and, lastly, male and female reproductive cells. The cells with the slender processes secrete the gelatinous ground-substance, which may be compared to the material forming the umbrella of jelly-fish.

The varying consistency of sponges, which may be soft, stony, leathery, horny, etc., results from the amount and kind of material secreted by cells of the mesoderm. In the Venus' flower-basket, these cell architects form large spicules of silica which are joined into a trellis. In the living bath-sponge, groups of cells congregate in the ground-substance, and secrete a network of cylindrical fibres of horny material. In calcareous sponges, the skeleton-cells form spicules which nearly always remain separate, and are always beautifully adapted for purposes of support. In addition to forming a support, the skeleton spicules, in many cases, afford a means of defence against small animals by forming spikes in the canals, or on the surface; and, further, it is improbable that any fish would repeat the experiment of eating a siliceous sponge.

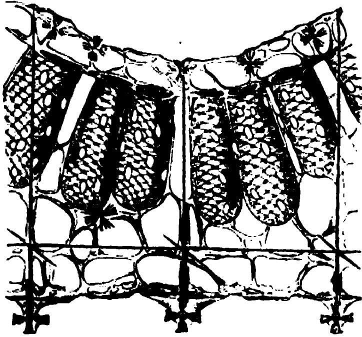
To return to the bread-crumb sponge. A dried specimen can easily be crumbled into powder, in which can be seen numerous glassy spicules, pointed at each end, and about an eightieth of an inch in length. The spicules, which are unaffected by most of the strong acids, are composed of silica, and are allied in composition to flint and opal.

Each needle is made up of concentric laminæ of silica, deposited round a fine central axial canal containing a thread of organic matter, and each is formed in a cell of the mesoderm. In this sponge the needles are separate, and scattered with scarcely any regularity in the ground-substance, excepting at the surface, where bundles of needles are joined by their ends to form the gauze-like network. In many sponges the rods or bundles of rods form a regular scaffolding.

Reproduction.

As regards the modes of reproduction, both male and female cells are found in the mesoderm, either in the same or in different specimens. The male cells in sponges generally give rise, by division of the nucleus, to masses of spermatozoa, each of the latter possessing a conical head and a long vibratile tail. The ova appear as large rounded cells, which, after fertilisation, undergo segmentation or division, first into two cells, and each of these again into two, and so on, until a mass of cells results, two kinds being present, one forming an outer layer covering the other. The outer layer of the now egg-shaped embryo, excepting at the narrow end, is composed of long, narrow, cylindrical cells, provided with cilia; and the inner mass is composed of large granular cells. The embryos appear as minute oval bodies, about the size of a pin's head. If a bread-crumb sponge be cut open in the autumn, they will be seen as bright yellow spots in the body-substance. By keeping specimens in a vessel of water, and examining them daily, the embryos will be observed being driven out of the oscules, and swimming about with the broad end forwards. After from twenty-four to forty-eight hours of independent roving existence, an embryo fixes itself by its broad end, and becomes flattened. By a remarkable transformation peculiar to sponges, the large granular cells of the

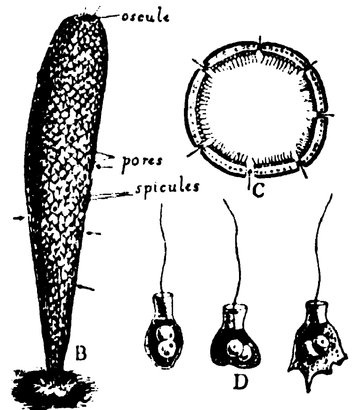
interior burst out and grow over the outer flagellate layer of cells, and the latter become the collar-cells of the adult sponge. A minute sponge with one oscule results from the development of the fertilised ovum. An extensive crust with numerous oscules may be regarded either as a colony in which each oscule represents an individual, or simply as one individual in which the growth of the body necessitates the formation of new channels for the conveyance of food materials.



SECTION OF WALL OF VENUS' FLOWER-BASKET, SHOWING SOFT PARTS.—After F. E. Schulze.

We are now in a position to answer the question, What is a sponge? It is obviously a living animal organism. The next question—the position of sponges in the animal kingdom—is not settled. All are now agreed that sponges come somewhere between the Protozoa and the rest of the animal kingdom, or Metazoa. It is accepted that sponges cannot be classed with Protozoa, for the embryo consists of definite groups of cells giving rise to distinct tissues. Some zoologists class sponges with the Cœlenterata. The opinion here adopted is that sponges form a special subkingdom—Porifera.

The bread-crumb sponge has been selected as an example for explaining the nature of sponges, because of the historical facts associated with it, and its occurrence round the British coasts. Its anatomy is, however, somewhat complicated; but there are other simple forms, the study of whose structure renders it possible to trace the path of development along which the more complex forms have proceeded. One of the simplest of sponges is *Ascetta primordialis*, found on seaweeds in the Mediterranean; in its simple unbranched condition it forms a minute white sac about a twenty-fifth of an inch in height, opening above by a wide round oscule, and narrowing below to a stalk. The walls are very thin and perforated by pores, through which water passes into the interior. The walls of the sac are composed of two layers, an inner lining of collar-cells, and an outer layer, consisting of a gelatinous matrix containing amœboid cells and transparent three-rayed spicules of carbonate of lime. A canal-system can hardly be said to have arisen since the walls of *Ascetta* are thin and not folded. The spicules support the walls and serve as a framework for the pores. By eliminating the spicular skeleton, and by supposing the tube or vase to be more globular, we obtain the "olynthus-form" which has been regarded as the hypothetical ancestor of all sponges. A canal-system arises when the walls grow thick or form folds or give off pouches or tubes. The folds or pouches may

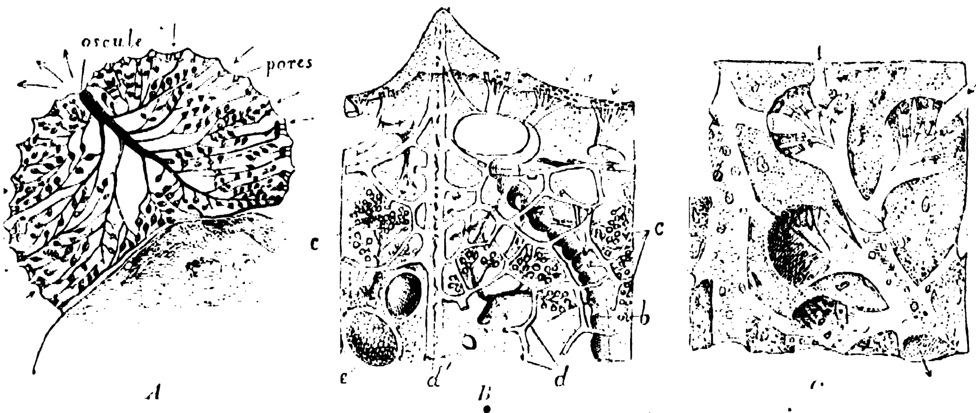


AN ASCON SPONGE.

A, Magnified 20 times; *B*, 80 times; *C*, Transverse section; *D*, Collar cells. (Magnified 700 times.)

be so close to one another that the spaces between and outside of them form channels, which are incipient in-current canals, the spaces in the inside or lumen of the folds forming the out-current canal-system.

The common ciliated sycon, a calcareous sponge found on seaweeds round the British coast, forms a white sac about an inch in height, and with a crown of glassy bristles round the orifice. The vertical cavity of the sac is surrounded by a wall of closely packed horizontal tubes, opening at their inner ends into the central cavity, but externally ending blindly. The central cavity of the sac is lined with flat-cells, and the radial tubes with collar-cells; and the walls of the tubes are perforated with small pores. Here the spaces between and outside the densely packed tubes are the in-current canals. In an equally common British sponge, *Grantia*, which forms small flat white bags, a rudimentary cortex covers the outer ends of the tubes. In *Grantiopsis* the cortex becomes quite thick. In more complex stages the radial tubes branch; and, finally, the collar cells clothe only the ends of branched tubes, thus giving rise to more or less spherical flagellated chambers. As the radial tubes become more branched, and the



TOILET-SPONGE.

A, Diagram of canal system. *B*, Section showing *a*, pores; *b*, canals; *c*, flagellated chambers; *d*, skeleton-fibres; *d'*, main fibre; *e*, embryo eggs. *C*, Flagellated whip-chambers. (Highly magnified.)—After F. E. Schulze.

mesoderm thicker, so the passages or in-current canals from the outside of the sponge to the outside of the radial tubes become more complicated. Common siliceous sponges develop in a different manner from the above-described calcareous ones, namely, from a hollow conical sac open at the top, and with a flat base; the spherical flagellated chambers at a very early stage forming a mammillated layer in the walls. *Plakina*, one of the simplest siliceous sponges, encrusts stones with a fleshy crust, consisting of a sac with a flat base attached to the stone, and with the rest of the walls forming simple folds. The spaces between and outside the folds form the in-current, and those in the lumen of the folds the out-current channels. Each of the flagellated chambers in the walls of the folds communicates with the in-current spaces through several pores, and opens into the out-current spaces by one large pore, the currents of water passing out by the central oscule.

The fine toilet-sponge possesses a more developed canal-system. The in-current and out-current parts of the water-bearing system are more definitely "canalised,"

and may be compared to the roots of a tree which divide into finer rootlets. The flagellated chambers form a convoluted cordon between the rootlets of the two systems. In the sea-kidney sponge of the Mediterranean the specialisation is carried to a still higher stage, each flagellated chamber being isolated from the rest, and having a slender canal leading to it, and one leading from it.

The soft tissues permeated by canals require a supporting scaffolding or skeleton, and in nearly all sponges it is the function of certain cells in the mesoderm to secrete skeleton-material. A few sponges possess no skeleton whatever, excepting the gelatinous ground-substance; in some also the skeleton is mainly or entirely composed of foreign particles of sand, spicules of other sponges, skeletons of Radiolaria or Foraminifera. The vast majority form in the ground-substance a skeleton which is composed of spicules of silica, or carbonate of lime, or of horny fibres. The sponges whose skeleton is composed of calcium carbonate form a distinct class—the Calcarea. Of those which secrete a siliceous skeleton, the glass-sponges form a second class distinct from the rest of the siliceous sponges. All the rest, including by far the largest number, are included under a third class, the common sponges (Demospongia).

The Calcareous Sponges,—Class **Calcarea.**

In this group the skeleton is formed of spicules of carbonate of lime, shaped

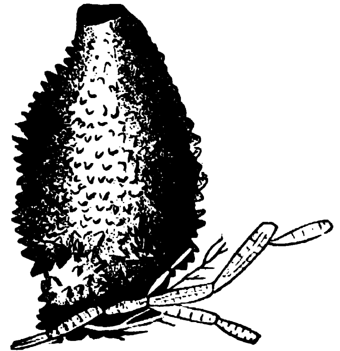


A CALCAREOUS ASCON SPONGE, *Leucosolenia* (magnified 4 times).

like three-rayed stars, four-rayed stars, or needles. The triradiate occurs most frequently in its typical form, the three rays being equal, in one plane, and forming

an angle of 120° with each other. The spicules are transparent and glassy when viewed separately, but white and opaque in mass. On placing a calcareous sponge in acid, the skeleton dissolves away with effervescence. The class is divided into two groups, namely, the Homocœla and the Heterocœla, in the former of which the collar-cells line the whole of the interior of the simple or branched sac; while in the latter they are confined to the radial tubes, or the ends of branched radial tubes or canals, the gastric cavity with a part of the canal system being lined with flat cells. The simple ascon sponge (*Ascetta primordialis*) forms a minute stalked sac open above, and with its thin walls perforated by pores and supported by triradiate spicules; the whole interior being lined with collar-cells. The simple sac may give off a stolon, whence arise other sacs, or it may branch, and the branches again divide forming a tree-like growth; or, lastly, the branches may join together and form a complicated meshwork of sacs or tubes. The allied *Leucosolenia*, shown in the illustration, is a branched ascon found on seaweeds in the form of clusters of small white tubes.

The ciliated sycon (*Sycandra*) and *Grantia*, are common among seaweeds and in rock-crevices on the British coasts; both sponges are sycons, *i.e.* with tubes radiating out horizontally from a central cavity, and in both are present the three kinds of calcareous spicules (needles, three-rayed, and four-rayed forms). The walls of the ciliated sycon are made up of closely-packed tubes, lined with collar-cells and opening into the vertical gastric cavity. Rows of three-rayed spicules, arranged in regular series, support the walls of the tubes, the blind ends of which are protected by tufts of needles; a layer of four-rayed spicules lines the walls of the central cavity, the fourth rays projecting inwards and upwards into the cavity so as to form a wall of spikes. When the current is flowing from the interior the crown of needle bristles round the oscule is expanded, but when the sponge is inactive the bristles fall together and cover the oscule. *Grantia* lives on seaweeds or hanging down from rocks, and several specimens are usually found together. They resemble small white leaves, or flat bags, averaging about an inch in length and one and a half in width, though sometimes much larger. When quite young and small they possess only one oscule, but larger specimens possess several on the thin margins. When the sponge is active, the flat leaf fills out like a small paper-bag. The leucons usually possess tubular or hollow knob-shaped bodies with thick walls, in which ramify a double system of canals, in-current from the surface to the flagellated chambers, and out-current from the latter to the gastric cavity.



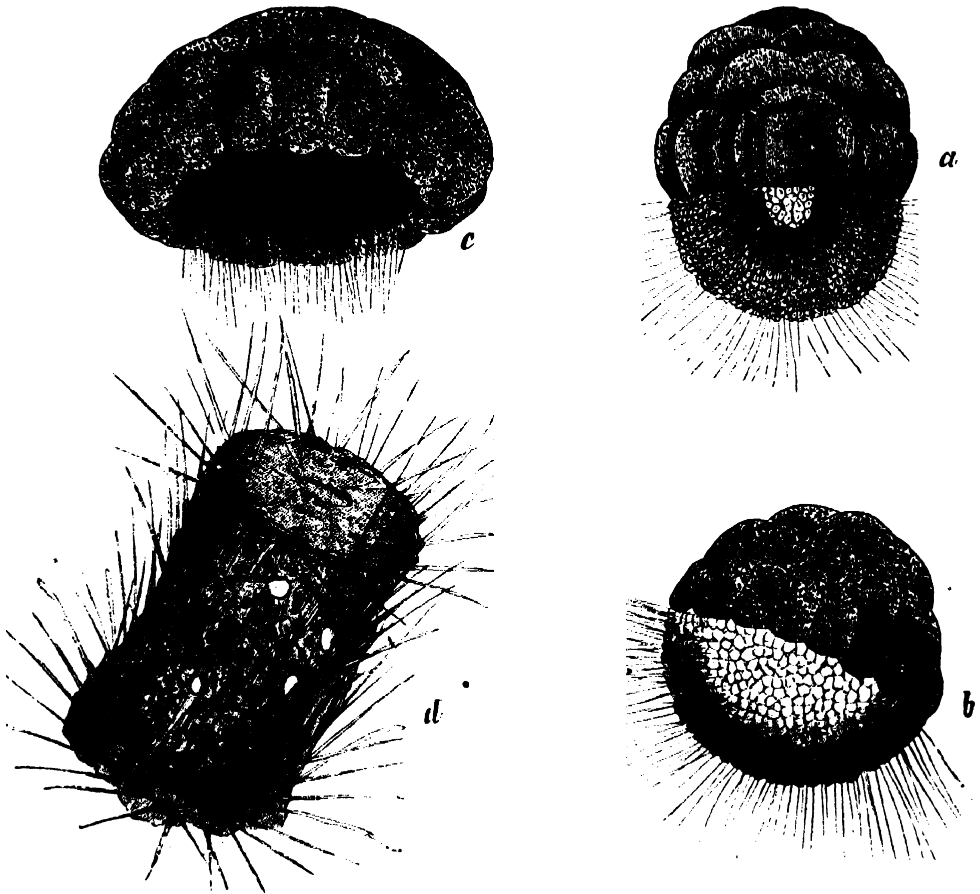
A CALCAREOUS LEUCON SPONGE, *Leucandra* (nat. size).

On making a section or teasing a fragment of a calcareous sponge in the spring, the minute embryos will often be seen. When the embryo leaves the parent sponge, it consists of an extremely minute oval cyst or vesicle (v) with a small central cavity, and is formed of two kinds of cells. The anterior half, or the part in front when the embryo is swimming, is composed of a number of long,

prismatic cells, each carrying a vibratile flagellum. The hinder end is composed of a smaller number of large rounded granular cells without flagella.

After the larva has swum about for a time, it becomes broader in the equatorial zone (*b*). The fore-half broadens out more and more till it forms a flat lid on the hinder hemisphere. Finally, the small cells lose their cilia and become completely invaginated into the interior of the large-celled hemisphere, which now resembles a cup with a double wall (*c*).

There are thirteen British species of Calcarea, and over two hundred from all



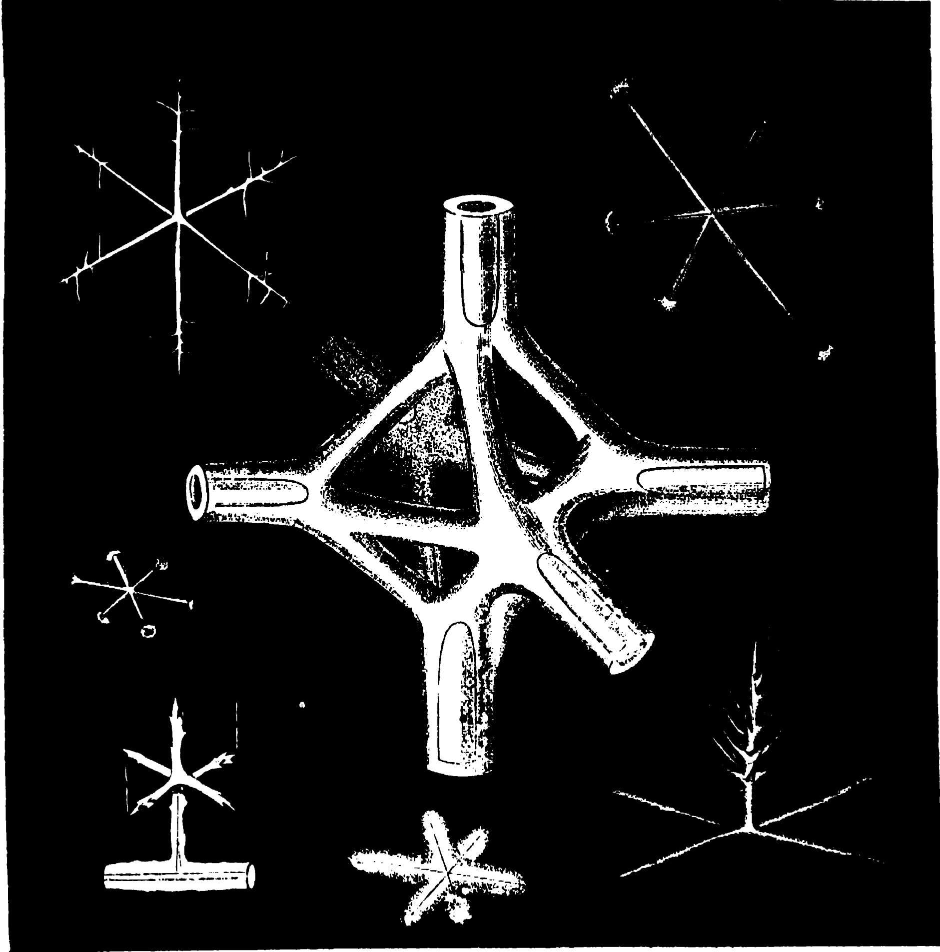
DEVELOPMENT OF *Sycon raphanus* (all figures enlarged).

parts of the world. They are almost confined to shallow water, the greatest depth from which they have been obtained being four hundred and fifty fathoms. Calcareous sponges prefer shade and avoid light, and are chiefly found in caves, under stones, in shells, or in the shade of dense thickets of seaweed.

SIX-RAYED, OR GLASS-SPONGES,—Class **Hexactinellida.**

In the sponges of this group the skeleton is built of spicules with three axes and six rays, intersecting one another at right angles through a common centre. A second characteristic consists in the comparatively simple arrangement and large

size of the thimble-shaped flagellated chambers, which attain an average length of $\frac{1}{250}$ of an inch in *Euplectella*. Leaving out of consideration the skeleton, the soft tissues typically form a tubular sac open at the top, and, with the walls, formed of five layers, an outer dermal and an inner gastral membrane with a layer of flagellated chambers suspended between and supported by subdermal and sub-gastral networks of fibres; the direction of the water current being always from the dermal to the gastral surface. The six-rayed spicule is the form best adapted to



SILICEOUS SPICULES OF SIX-RAYED, OR GLASS-SPONGES; IN THE CENTRE AN EIGHT-SIDED INTERSECTION NODE OF A FOSSIL VENTRICULITE SPONGE.

support a soft walled sac of this description, one axis being vertical to the walls, and the other two tangential; the rays of each spicule uniting with those of adjoining spicules to form a framework. The typical spicule has six equal rays at right angles to each other, with an axial canal in the centre of each. When four of the six rays disappear, leaving only a glassy rod, the history of such a spicule is betrayed by the presence of a minute cross, which is all that remains of the axial canals of the atrophied rays. Endless modifications of the typical form may occur. One or more of the six rays may develop more than the rest; one or more may be

suppressed, resulting in the formation of five-, four-, three-, two-, or one-rayed spicules. Again, the simple principal rays may branch or give off tufts, which may be pointed or end in discs. Further, the rays may be curved, or become beset with spines. The spicules either remain loose and separate in the soft tissues or become joined by apposition and intertwining, or by fusion of rays by means of layers or bars of siliceous cement.

The glass-sponges are divided into two groups, the Lyssacina and the Dictyonina. In the former the spicules are loose and separate, fusion when present occurring in the older parts of the sponge; in the latter the principal spicules form a solid framework even in the earliest stages of growth. *Bathydorus*, a Lyssacine sponge, which has diverged but slightly from the simple sac form, was dredged from two thousand nine hundred fathoms in the North Pacific, and forms a soft thin-walled tube about seven inches in height and two inches in diameter. In the Venus' flower-basket (*Euplectella*), shown in the central illustration of the coloured Plate, there are certain modifications of the simple sac type. Firstly, there is a lid at the top, and further, the walls of the tube are perforated by large round holes about one twenty-fifth of an inch in diameter. The water can thereby pass direct from the outside into the gastral cavity or lumen of the tube; each aperture is surrounded by an iris-like membrane which can probably close the orifice. These parietal apertures, in the whole thickness of the wall, must not be confused with the very minute in-current pores through which the water passes into the sponge-substance. In life, the glassy framework — frequently seen as an ornament — is covered with the brownish gelatinous flesh. The glassy skeleton forms a curved tube from 10 to 18 inches in length, shaped like a cornucopia, the curve taking place at the junction of the lower and middle third. *Euplectella oweni* from Japan, which closely resembles *E. aspergillum*, forms a straight cylinder, devoid of the collar round the lid and without ridges on the walls.

The glass-rope sponge (*Hyalonema*) of Japan belongs to a group of Lyssacine sponges, characterised by the possession of amphidiscs, spicules with a straight shaft, at each end of which is a large toothed disc, resembling the ribs of an umbrella. The spicules are sometimes large enough to be visible to the naked eye, and vary in different species from the hundredth to the twenty-fifth of an inch in length. The rope was first brought to Europe about 1830, and for years formed the subject of controversy as to its nature. The Japanese glass-rope sponge forms a solid-looking, ovoid, thick-walled cup, the top of which is closed by a thin sieve-like lid with an imperforate cross-shaped area. From the lower end of the body arises the long siliceous glass-rope, composed of twisted strands of spicules which anchor the sponge in the mud. For a varying distance below the body, the tuft is invested by a parasitic zoophyte. A transverse section of the cup shows a cavity, in the centre of which is a spike which is the upper end of the glass-rope projecting into the interior. From the central spike septa radiate; these are convex along their upper margins, and attached at their ends to the imperforate bands on the operculum. The walls contain the much-folded layer of flagellated chambers.

The spicules of the tuft are pointed at the upper end, and terminate below in minute four-pronged anchors. Many of them are marked with a spiral ridge,

minutely serrated on the upper edge, and thereby offering resistance to the uprooting of the tuft from the mud. The length of specimens varies from 20 to 30 inches.

The Japanese species is obtained from off Tokyo, from a depth of three hundred and forty-five fathoms, and is fished for with long lines, weighted and provided with hooks, which are dragged along the bottom. Eighteen species have been obtained from the Atlantic, Pacific, and Southern Oceans, from depths ranging from a few hundred up to two thousand five hundred and fifty fathoms. The allied *Semperella*, shown in the right-hand illustration of the coloured Plate, occurs in one hundred fathoms off the Philippines. It forms a subcylindrical stock, about 12 inches in length and 2 inches thick, terminating in a dense tuft about 3 inches long. The lace-like skin covers a complicated labyrinth of tubes. Another Philippine form (*Polylophus*), represented in the bottom right-hand corner of the same Plate, has small thick-walled hemispherical cups, with tufts of spicules growing from conical projections on the walls, and passing down to form root-tufts. This sponge is remarkable for producing buds, which become detached and develop into complete sponges. In the middle of the lower part of the Plate is shown a species of another genus, known as *Periphragella*, from Japan, which forms a curved funnel, on the outer wall of which is a network of tubes which have branched off from the main body. In *Farrea*, seen in the left-hand bottom corner of the Plate, the body is formed of forking branched glassy tubes, the walls of which consist of spicules whose rays have fused into a rigid framework. *Sclerothamnus*, from three hundred and sixty fathoms off Timor, is a remarkable Dictyonine sponge, which forms a bush two or three feet in height, with the branches marked with a spiral band.

Another beautiful type is Carpenter's glass-sponge (*Pheronema*), shown in the illustration on p. 530, which consists of a thick-walled cup, narrowed at the orifice, and giving origin below to a thick root-tuft of spicules; the first specimens were dredged from a depth of five hundred and thirty fathoms off the Faroe Islands.

Glass-sponges, with one or two exceptions, have been obtained in deep water, from ninety to two thousand nine hundred fathoms. Previous to the deep-sea dredging expeditions, specimens had been found in only a few localities, and the procuring of them had been due more or less to accident. Thus the Japanese fishermen, while in quest of deep-sea fish, brought up glass-ropes, which became marketable commodities. Similarly, the Malays found it would pay to explore for submarine treasure, and constructed their bamboo dredge.

Fossil Hexactinellida are found abundantly in the Chalk. The *Ventriculites*, found in Chalk flints, are the skeletons or casts of glass-sponges.

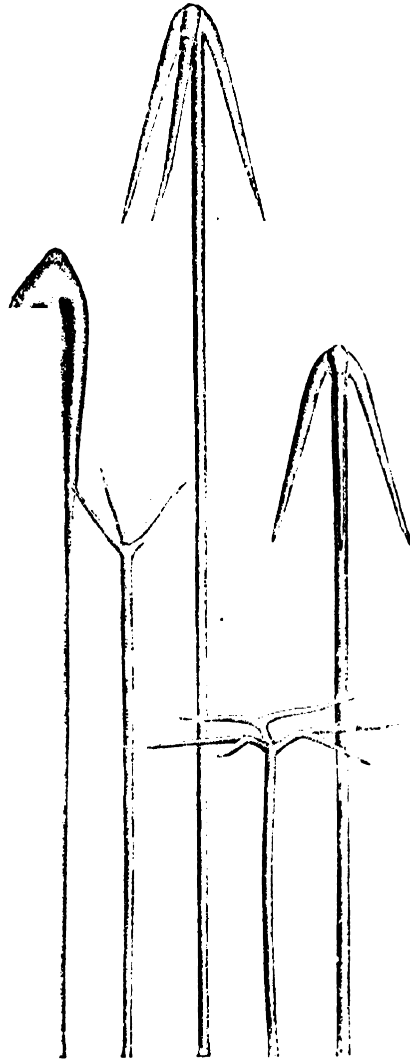
THE COMMON SPONGES,—Class **Demospongia.**

The common sponges include all those which do not come under the designation of calcareous or glass-sponges. A negative definition is unsatisfactory, but it is difficult to frame a positive one which will apply to all divisions of this class. Most common sponges are siliceous, while such as are horny are probably derived from siliceous types. They are divided into four orders. In the first or four-rayed

sponges the spicules typically possess four axes and four rays, and resemble caltrops. The fleshy sponges, with little or no skeletal structure, form a second group; while a third group includes the monaxonid or uniaxial sponges, with the skeleton typically built up of needle-shaped spicules, with one axis. The horny sponges form a fourth group.

Four-Rayed Sponges,—Order Tetractinellida.

In this order the siliceous spicules of the skeleton have four axes and four rays, and typically are shaped like caltrops. The typical form undergoes numerous modifications, one of the commonest consisting in the lengthening of the vertical ray, and the bending of the other three rays towards the long shaft, an elegant anchor -shaped spicule resulting. The anchor form may, however, have originated from the branching of a uniaxial or rod-shaped spicule, and not from the alteration of a four-rayed caltrops form. The three prongs of an anchor may point downwards, upwards, or horizontally outwards, and in the last case they are frequently forked. The Lithistida (stony sponges), one of the groups into which the order is divided, are characterised by the presence of peculiar spicules, known as desmas, in which a minute rod or caltrops is surrounded by concentric layers of silica: at the margin of the plate or disc thus formed, branched and often tuberculated processes are given off, which usually join or interlock with those of other spicules to form a dense stony skeleton: but sometimes the desmas are not linked together, and the lithistid sponge is quite soft. In addition to the larger forms of spicules, such as anchors, which form the skeleton, there are minute, coiled, spiral, or stellate spicules scattered in the flesh. A well-developed crust is frequently present; and in *Geodia* the crust is composed of solid siliceous globules packed into a layer, beneath which lie the anchors with the prongs next the crust, and the long pointed shafts passing in centripetally. The four-rayed sponges are divided into the groups Choristida and Lithistida. In the former the spicules are loose and separate; and in the latter desma spicules are present, and usually fused or interlocked so as to form a stony skeleton. The Choristida frequently form yellowish white, leathery, nodulated cakes, plates, and crusts. The Lithistida, or



SILICEOUS SPICULES OF FOUR-RAYED ANCHOR SPONGES (magnified 200 diameters).

stony-sponges, are usually brittle and friable, or of stone-like hardness. The four-rayed sponges belong mostly to shallow water, but a few specimens have been obtained from depths of nearly two thousand fathoms.

THE FLESHY SPONGES,—Order CARNOSA.

These form a small group of uncertain systematic position, their chief features being the possession of a tough rind, enclosing a softer pith, the absence or slight development of a skeleton, and the highly-developed canal-system. They appear to be related to the four-rayed sponges. The soft pith contains the flagellated chambers and the canals leading to and from them. The genus *Chondrilla* possesses isolated siliceous spiny spheres, especially situated along the courses of the canals and beneath the rind. The allied *Chondrosia* of the Mediterranean takes the form of



SEA-KIDNEY LEATHER SPONGE (*Chondrosia reniformis*). *a*, Specimen cut open.

leathery knobs or cakes with a slimy surface. The usually solitary oscule is irritable, and contracts slowly when the sponge is taken from the water. Fishermen call this sponge, sea-flesh or sea-kidney. The ground-substance contains no skeleton of silica or horny material; and the in-current and out-current canals form two sets of tree-like branched systems with the flagellated chambers interpolated between the final twigs of each.

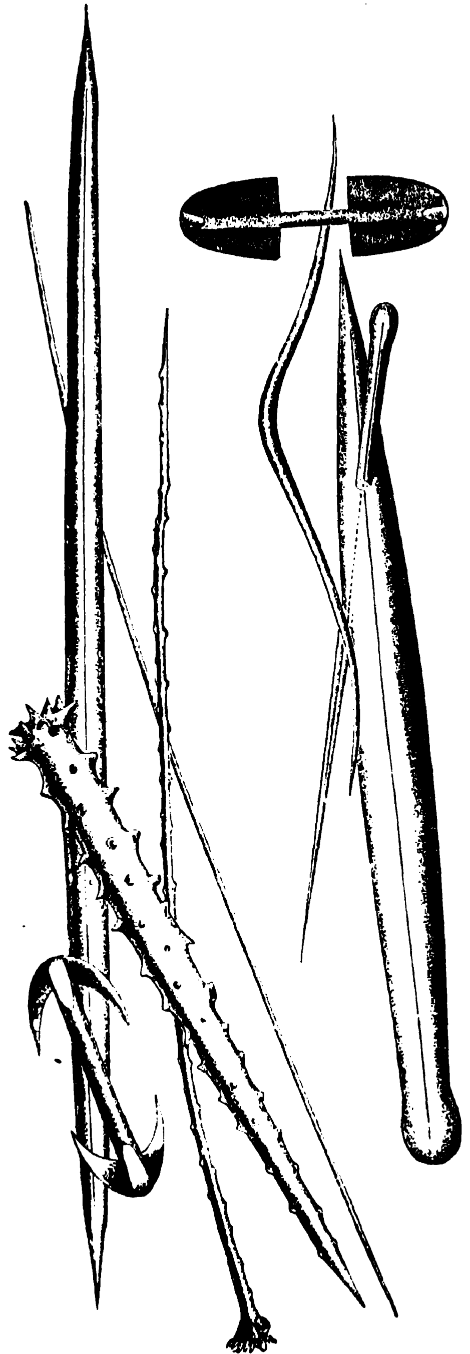
SINGLE-RAYED SPONGES,—Order MONAXONIDA.

These sponges are those most frequently met with on the British shores and in shallow water throughout the world. The skeleton is mainly built up of uniaxial siliceous needles or rods, which may be isolated and scattered, or united into bundles by the horny cementing substance, spongin; while the bundles may be joined in various ways to form scaffoldings for the support of the soft parts. The spicules are shaped like spindles. In addition to the large spicules forming the bulk of the skeleton, and on this account called skeleton-spicules, in some groups minute forms abound in the soft substance, and are termed flesh-spicules. The latter are frequently shaped like buckles or double anchors, with prongs at each end. A transition can apparently be traced from this group to the horny

sponges; the siliceous needles becoming less numerous and the horny substance more abundant, till, in the true horny sponges, such as the toilet-sponges, the skeleton consists entirely of horny fibres. The ocellated *Chalina*, frequently cast ashore round the British coasts, exhibits an intermediate condition between the siliceous and horny forms. By teasing out and examining a few fibres under the microscope, a fine core of siliceous spicules will be seen in the axis of each thread of spongin.

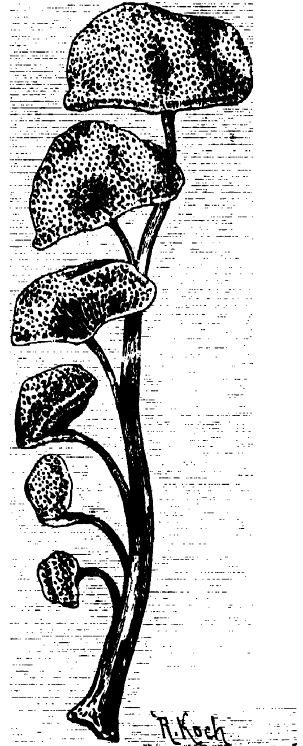
The illustration on p. 528 represents a group of sponges growing together. Near the base of the black seaweed on the stone there arises the much-branched Desmacidine sponge, so called from its buckle-shaped spicules; while from the left branch of the former grows a flat alga encrusted by another sponge of the same order, and of a dull yellow colour; and at the top of the colony is the violet *Spongelia*. The illustration to the left represents another sponge of this group (*Axinella*), common in the Mediterranean. In life this sponge is of a yellowish colour, and the oscules present a radiate arrangement like the polyps of a branch of fan-coral. The illustration on p. 543 illustrates a sponge dredged by the *Challenger*, and known as *Esperiopsis challengeri*, from six hundred and thirty fathoms, east of the Celebes. The largest specimens are about 8 inches in height. From a solid, strong stem six or seven stalks are given off at gradually

A SINGLE-RAYED SPONGE, *Axinella* (nat. size).



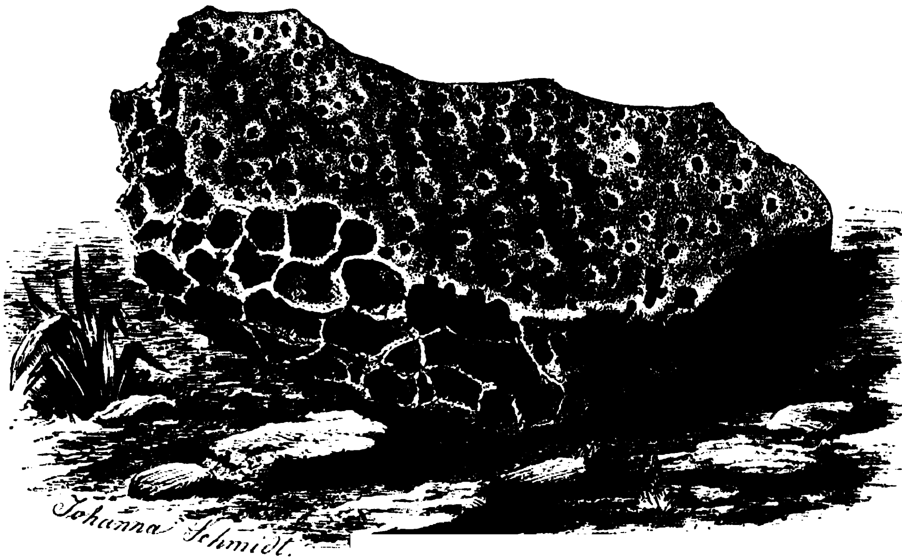
SILICEOUS SPICULES OF MONAXONID SPONGES (magnified 200–300 diameters).

increasing intervals from below upwards, and each bearing a hemispherical cup or ladle, convex outwards. The in-current pores are on the concave, and the out-current on the convex surface. To this order belongs the Neptune's cup sponge (*Poterium*), attaining a height of 3 or 4 feet. It includes also the boring-sponges (*Cliona*), in which the skeleton consists of scattered pin-shaped spicules. To compensate for the inefficient support, the sponge excavates into limestone, chalk, or shells. Great importance is attributed to the destructive power of these sponges by Prof. Schmidt, who points out that considerable portions of the coasts of the Mediterranean consist of limestone, the disintegration of which has been greatly hastened by the operation of boring-sponges. In many parts the outlines of the coast have consequently been much altered, and along the Dalmatian shore, for a distance of a thousand miles, one may find the beach thickly strewn with stones completely riddled with the holes made by these sponges, as shown in the illustration on p. 544. The causes of this property of the burrowing-sponges are not known; but there are two theories, mechanical and chemical. According to the former, the sponge bores by means of the grinding of its siliceous spicules against the softer limestone. The action would be assisted partly by the action of the contractile substance of the sponge-body, and partly by the currents of water traversing the canals. On examining the galleries of a shell or piece of limestone with a lens, the surface is seen to be pitted with minute hemispherical cavities, giving rise to a finely shagreened appearance. The shagreen surface is characteristic of the action of a burrowing-sponge, and serves to distinguish the cavities and hollows due to the sponge from those caused by worms, molluscs, or the action of water. Certain minute five-sided plates were formerly supposed to assist in the excavating process, but are now known to result from the breaking down of the organic layers of the shell. On the other hand, the advocates of the chemical theory attribute the excavating properties to the secretion of carbonic acid by the sponge, which is thus enabled to dissolve the carbonate of lime of the shell or limestones; but an objection lies in the fact that carbonic acid is incapable of dissolving the organic plates of shells. Recently it has been urged that the power of contractility possessed by the sponge is a powerful aid in the work of excavation. Burrowing-sponges are a trouble in oyster-culture, and it is suggested that at the time when the free-swimming sponge-embryos are formed, a bank of old shells should be placed between the oyster-beds and the tide. The bank would filter off the embryos, which would grow in the old shells, and be subsequently destroyed by immersion in fresh water. A figure of a fragment of limestone thus perforated by sponges is given on the following page.



Esperiopsis challengeri (½ nat. size).

Fresh-Water Sponges. To the group under consideration belong the fresh-water sponges (*Spongillidæ*), which live in ponds, canals, lakes, and rivers all over the world; and have been known to infest the pipes supplying a city with water. The two commoner British species (*Euspongilla lacustris* and *Ephydatia fluviatilis*) grow on the piles of bridges, the sides of locks, the stems of water-weeds, or form crusts on the bed of rivers. *Euspongilla* forms bright green crusts, from the surface of which long, simple, or branched stems arise; or the surface of the crust may be simply conulated. This green colour is due to granular bodies which crowd the cells near the surface of the sponge. Some naturalists consider these bodies to be chlorophyll granules similar to those of plants; others regard them as single-celled algæ. The chlorophyll, in the presence of sunlight and water, splits



LIMESTONE BORED BY SPONGE.

up the carbonic acid evolved by the sponge into carbon and oxygen, the latter being used by the sponge for respiration. Fresh-water sponges growing in shady places are of a pale grey or yellowish white colour; and when bright green specimens are kept in the dark, they lose their green colour. The surface of a fresh-water sponge is covered with fine pores, while here and there a few large oscules are visible. From the pores fine in-current canals pass down to the flagellated chambers, and from the latter proceed the rootlets of the out-current canal-system. With a lens the spindle-shaped siliceous spicules of the skeleton can be made out. They are about one-fiftieth of an inch in length and unite in bundles which partly surround the canals, and are partly scattered irregularly in the ground substance; with the naked eye the bristling points can be seen projecting from the surface. If a specimen be examined in autumn, there will generally be found crowding the meshes at the base of the crust a number of small yellow spheres, about one-twelfth of an inch in diameter, known as gemmules. They possess a firm shell, with a small circular pore at one spot covered only by thin membrane. A gemmule is a kind of internal bud, and is capable of developing into a new sponge.

When the season unfavourable to the life of the sponge arrives, a number of wandering cells collect together into a mass which becomes coated with a horny covering. Outside this a layer of siliceous spicules is secreted. In *Ephydatia* these spicules are, from their peculiar shape, termed amphidiscs, two toothed discs being united by an axle, the layer of amphidiscs being arranged with the axles vertical to the surface of the gemmule. In the succeeding spring the cellular mass in the interior bursts out through the pore, and develops into a sponge. The gemmule-spicules of *Euspongilla* are shaped like curved needles pointed at each end, and with a granular surface. Gemmules are formed, but apparently only rarely, in a few marine sponges, such as *Cliona* and *Chalina oculata*. These bodies are formed also by the fresh-water Bryozoa. In addition to this asexual or vegetative formation of gemmules, fresh-water sponges also form ova and spermatozoa. When the ova are fertilised they undergo segmentation, and form oval ciliated embryos which are about one-seventh of an inch in length, and are easily to be seen swimming about in a glass vessel of water. They swim with the broad end forwards; the anterior upper half is dark and semitranslucent, the posterior lower half glistening white and opaque.



EMBRYO OF A FRESH-WATER SPONGE (magnified 100 diameters).

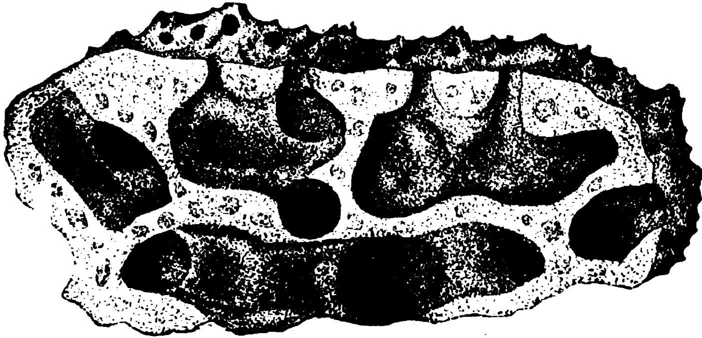
HORNY SPONGES,—Order CERATOSA.

In this group, of which ordinary toilet-sponges furnish examples, the skeleton is chiefly composed of fibres of a horny substance, termed spongin, and allied in composition to silk. In the toilet-sponges the fibres of the skeleton form a close felt-like network of soft elastic texture; but some horny sponges are hard and brittle, and others of the consistence of indiarubber. In most of the group foreign particles, such as grains of sand, or siliceous spicules of other sponges, are present in the fibres; and in some the foreign bodies form a thick core covered with a thin coating of spongin. Even in the softest toilet-sponges foreign particles are included in the main fibres. The large purple fan-shaped *Ianthella* from North Australia belongs to this group; also *Lufforia archeri* (Neptune's trumpet) from Yucatan, forming a magnificent cornucopia, five feet in length. *Darwinella* possesses peculiar horny spicules.

Toilet- and Bath-Sponges. The sponges commonly seen in shops may be arranged under three species, all of which occur both in the Mediterranean and West Indies, namely, *Euspongia officinalis*, variety *mollissima*, the fine turkey- or toilet-sponge; *E. zimocca*, the hard flat disc-shaped sponge; and *Hippospongia equina*, the common bath-sponge or horse-sponge. Under these species are included a large number of "varieties" and "grades," classified according to form, quality of texture, colour, locality, etc. The sponge-merchant can define the exact locality whence a specimen came, by observing the presence of characters which the naturalist would not regard as specific. The merchant classifies his material into

grades, and uses names expressing the locality, texture, etc. The softest and finest is the Turkey cup-sponge, which usually forms deep or shallow cups. The whole outer surface of the dense horny network is covered with minute holes, which correspond to the groups of in-current pores; in the cavity of the cup are a few large holes about three-eighths of an inch in width, distributed irregularly or with a tendency to a radiate arrangement. The large holes are the oscules or out-current apertures. The second species is the zimocca, or hard-sponge, typically forming rounded discs, convex below and flat at the top. The pores are arranged on the outer side or margin, and a number of oscules cover the flat upper surface. The texture is denser and less resilient than that of the toilet-sponge, which it somewhat closely resembles. The microscope shows the cause of the denseness to lie in the thickness of the fibres composing the skeleton-network.

The common bath-sponge, or horse-sponge (*Hippospongia*), presents such wide differences from the first two forms, that the naturalist places it in a different genus. The holes on the surface of the loaf-shaped hemispherical mass do not correspond to those in a toilet-sponge. The in-current and out-current orifices are in



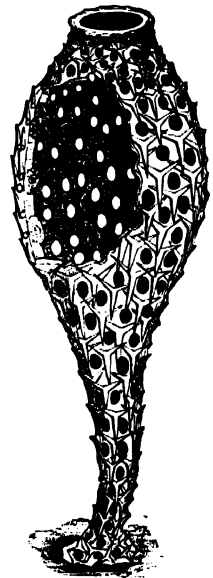
SECTION OF COMMON BATH-SPONGE.

the walls of the wide canals which permeate the whole sponge-body, so that the bath-sponge is really composed of much folded layers, or lamellæ, with the canal-system in the thin walls of the lamellæ. The large holes on the surface are "pseudoscules," and the tortuous passages into which they open are "vestibules" to the true pores, which can be seen on the walls. The pores corresponding with those on the outer surface of a toilet-sponge may be deep in the interior of a bath-sponge. The elephant's ear-sponge from the Adriatic is a variety of *Euspongia officinalis*. It forms a huge lappet, the edges of which may unite to form a funnel-shaped cup two or three feet in height; the pores are on the outer side, and the oscules in groups on the inner. Cut up into flaps a few inches square, these sponges are useful for house-cleaning, etc.

Many of the commoner kinds of sponges, termed hard-head, reef, etc., come from the West Indies, and are included under *E. zimocca*. The bath-sponge is less durable and more easily lacerated than the toilet-sponge, and has more foreign particles in the fibres. In their natural condition toilet- and bath-sponges look very different from the sponges in daily use. On seeing sponges in their natural state, one wonders how it was discovered that they formed skeletons possessing such useful qualities. A sponge living at the bottom of the sea appears

as a shining, blackish, fleshy lump, which cuts like raw meat, no trace of the horny network being visible. The discovery would probably result from finding cast up specimens with the skin and flesh partly rotted away from the more durable skeleton. A toilet-sponge when alive is a blackish, cup-shaped fleshy mass, with its surface covered with minute conical elevations. In the hollow of the cup are the oscules, which appear smaller than in the skeleton, and are capable of dilating and contracting. During life currents rush out of these holes. On the outer surface of the sponge, by very careful inspection, sieve-like groups of pores will be seen in the skin, between the conical elevations.

When a living sponge is torn or cut, a good deal of glutinous substance flows away. The dark skin covers a light yellow fleshy substance, in which the canals leading to the oscules are conspicuous. The walls of the canals are greyish, some being filled with mud, others containing a marine-worm or crustacean, others, again, being empty. The skin-pores open into subdermal spaces beneath, and from the floor of the latter canals branch into the body-substance. The smallest canals finally open into minute pyriform flagellated chambers; and from each of the latter there arises a rootlet of the out-current canal-system. What is commonly known as the sponge forms a supporting network of fibres in the gelatinous ground-substance, the horny skeleton forming a kind of scaffolding. The fibres are yellowish and translucent, and built up of concentric layers surrounding a thin axial thread. Foreign particles, such as sand-grains, flinty spicules of other sponges, etc., are included in the main fibres. Each growing fibre is surrounded by cylindrical cells which secrete it. When a fresh batch of cells secretes a new layer, foreign particles on the surface of the fibre become included within the new coating. The embryos are minute oval bodies, which swim by means of their cilia, and lead an independent life for a day or two. They then settle down by becoming fixed at one end, and develop into sponges.



Ascetta primordialis. After Haeckel.

In addition to sexual reproduction, there is also vegetative propagation. This characteristic has been made use of for cultivating sponges by cuttings.

SPONGE-FISHING.

Sponges are found in depths ranging from two to one hundred fathoms, and the methods of collecting depend both on depth and locality. Off Dalmatia the primitive method of harpooning is still employed. Two men go out in a small boat; one rows, the other leans over the edge holding a long fork. If the water ripples, the rower throws in a half circle in front of him a few pebbles dipped in oil. The Greeks employ a submarine spyglass, which simply consists of a pane of glass let into the bottom of a tube or bucket. By this means they do away with the effect of the surface ripples. In the Levant in depths of five to fifty fathoms divers are employed, either naked or provided with a diving-dress. In the former

case, the diver, with a bag round his neck, takes hold of an oblong white stone, with a cord attached; he breathes vigorously for a few minutes, and plunges in head foremost, holding the stone in front of him. He can only remain at the bottom at the utmost for three minutes, during which time he hastily snatches up the sponges, puts them into the bag, pulls the cord, and is drawn up. After the first descent of the season he comes up with his nose bleeding. If this does not take place it is considered a bad sign, and the diver will not consider himself fit to continue the work. Divers with dresses can remain for an hour in depths of from five to fifteen fathoms, but only for a few minutes in from twenty to fifty fathoms. In depths over fifty fathoms a drag-net is used, either from a vessel or hauled along from the shore. The net is fixed to a frame six yards in length and one yard in height; this is composed of camel hair, and has four-inch meshes. The sponges are taken ashore, pressed, squeezed, and rinsed, till the dark skin and fleshy glutinous substance has been got rid of, or they are exposed for a short time, and placed in a staked enclosure under water; in a few days the soft animal substance is trodden out, and the specimens are strung up to dry.

In a map of North America, the tongue-like peninsula of Florida will be seen projecting between the Atlantic and the Gulf of Mexico. The tongue extends beneath the sea as a submarine plateau, on which coral-reefs have formed, parallel with the southern and western shores of the peninsula, but separated from the mainland by shallow channels. From the point of the tongue extends a chain of small islands, or "keys," formed from coral growth and its fragments. The plateau forms a south-eastern expansion, the Great Bahama Bank, which sinks along its eastern margin by a stupendous declivity of over ten thousand feet to the great depths. The reefs on the plateau form rich sponge-beds, extending over an area of several thousand square miles. Previous to 1840 the existence of these valuable submarine beds was unknown. Now they afford a means of livelihood to many thousands of men, and nearly a thousand vessels are employed in collecting the crops.

The origin of the sponge-fisheries in the West Indian region was due to an accident. Previous to 1840 all the sponges of commerce came from the Mediterranean. In that year a member of a Paris firm of Mediterranean sponge merchants was wrecked on one of the Bahamas, in the course of a passage from Jamaica to Europe. He noticed that a great number of sponges were in use among the inhabitants, and was told that they were obtained from the waters round the island. On his return to Paris he arranged for consignments, and thus the Bahamas trade became established. In 1849 a cargo of sponges from Key West, Florida, arrived in New York, and was about to be thrown away as unsaleable; the cargo was purchased, however, by a firm, which established a branch at the new locality, and thereby founded the Florida trade.

When the inhabitants of the Bahamas and the Florida Keys found it would pay to collect sponges, their spirit of enterprise was awakened, and putting off in search, they continually found reefs overgrown with crops. Gradually the vessels increased in number and tonnage, till the fleets amounted to seven or eight hundred craft, mostly schooner-rigged, and of from five to twenty-five tons burden. All over this region one method alone is in use, that of hooking the

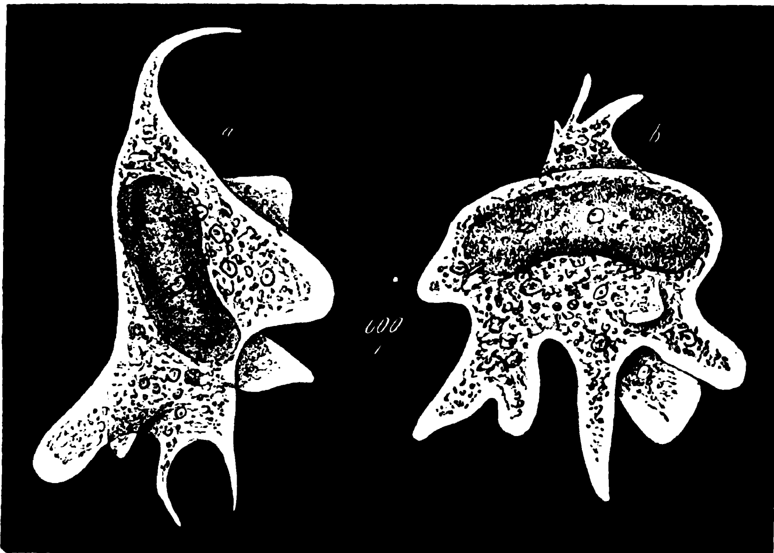
sponges up with a three-pronged fork provided with a very long wooden handle. Each boat carries a varying number of small dingheys. Two men are apportioned to a dinghey, one for sculling, the other for hooking. The hooker leans over the side, and views the surface of the reefs through a sponge-glass. Great skill is required in sponge-fishing; indeed, the difficulty of hooking up a small dark object in twenty or thirty feet of water, and often in a strong current, can be imagined. Once a week the fleet returns to some selected locality to unload its cargo into a crawl,—a staked enclosure covered with a few feet of water. The preceding week's catch, with the skin and fleshy matter almost rotted off, is now beaten, squeezed, hung in strings to dry in the sun, and finally packed in bales, and sent to Nassau and Key West. Sponges used to be sold by weight, but owing to the tendency to absorb moisture, and to the prevalence of the fraudulent practice of weighting them with sand, they are now valued according to size, shape, quality of fibre, etc. The fine toilet-sponge is found chiefly along the eastern shores of the Mediterranean, from Trieste round by the Levant to Tripoli. The distribution of the bath-sponge extends from East Greece, along the Levant and the North African shore, and the zimocca-sponge from the Levant to Tripoli. Good qualities of commercial sponges grow in the Red Sea; the Great Barrier Reef off the north-east of Australia would probably yield a large supply. The bulk of the harvest of sponges from Bahamas and Florida consists of common bath-sponges.

R. KIRKPATRICK.

CHAPTER XVI.

THE LOWEST ANIMALS,—Subkingdom **PROTOZOA.**

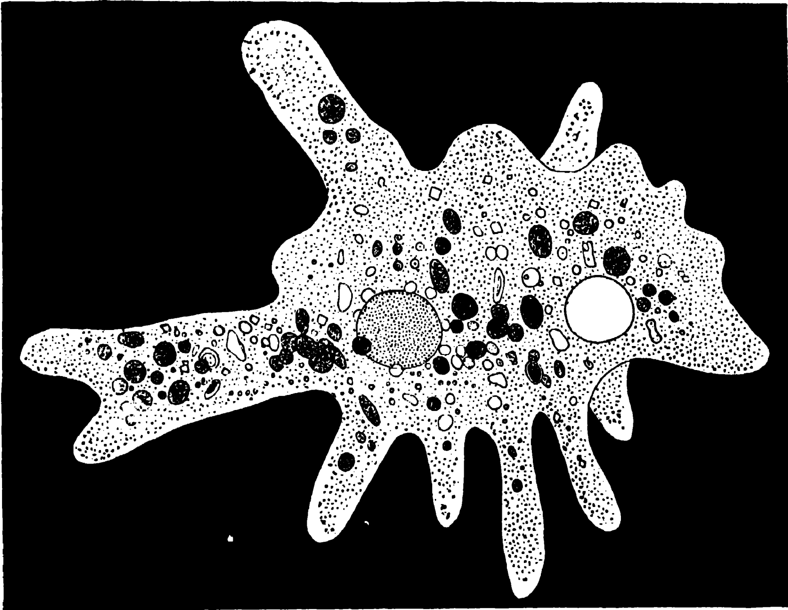
Characteristics. THE lowest animals belong to a world invisible to the naked eye, a world whose very existence was unknown two hundred years ago, despite the fact that its inhabitants abound on every side. In 1755 Rösel von Rosenhof saw sticking on the side of a glass vessel of water and weed a tiny particle of jelly, the movements of which attracted his attention. "It fastened itself," he writes, "on the side of the glass; and since, like animals, it moves, although very slowly, from place to place, and thereby continually alters its form, and as I frequently examined the water with a magnifying-glass, the creature was necessarily discovered; as soon as I touched it, it contracted itself into a sphere and



PROTEUS ANIMALCULE.
The same animal in different shapes. (Magnified 600 diameters.)

fell to the bottom." Rösel removed the specimen to a watch-glass, and observed it continually changing its shape. In consequence of this peculiarity, he named the animal "the small Proteus" after the monster of fable. Later the animal was named *Amœba*, as the name *Proteus* had been bestowed on another animal. An amœba is composed of a small particle of living substance, called protoplasm, and resembles a tiny blob of jelly, which continually but slowly changes its shape. The amœba is

generally found on the ooze of ponds, or the under surface of the leaves of aquatic plants, but especially amongst conferva, in clear gently flowing water. When first caught, the animal will appear as a tiny yellowish semitranslucent globular speck, about one-hundredth of an inch in diameter; presently it becomes beaded with rounded projections, some of which grow longer at the expense of others and of the body, and may give off one or two branches. By the projection of these processes, or pseudopods, the amœba moves along in the direction of the longer ones. "Sometimes," writes Leidy, "the animal creeps onward in a flowing manner with comparatively simple cylindroid form, occasionally emitting a single pseudopod on one side or the other. More commonly, in movement, it assumes a dendroid or palmate form, or sometimes, diverging from the directly onward course, it becomes more radiate in appearance. Not unfrequently it assumes more or less grotesque



PROTEUS ANIMALCULE, (highly magnified).

shapes, in which almost every conceivable likeness may be imagined." The body, of the amœba is full of granules, which render it semiopaque, with the exception of a thin clear outer hyaline zone, and near the centre is a globular or discoid body, known as the nucleus, composed of a denser protoplasm than that which surrounds it. Division of an amœba into two is preceded by division of the nucleus. Near the latter is a clear spherical space—the contractile vacuole—which gradually expands, rather suddenly collapses, and reappears at the same spot, the systole and diastole being slow and continuous. The contractile vacuole contains a clear liquid, which is expelled on the collapse of the vacuole. This organ probably serves the double function of respiration and excretion. The amœba is omnivorous, but is chiefly vegetarian, and browses on tender leaves, or feeds on diatoms and other algæ; it surrounds the food-particle or organism with the protoplasm of its body or of a pseudopod, and the ingested particle sinks in, surrounded by a zone of water; frequently there are several food-balls in the body of the animal. The

food can be taken in, and the remains ejected at any point, but the latter frequently appear to be cast out at one spot behind the nucleus and contractile vacuole. The animal reproduces by dividing into two halves, each containing a portion of the original nucleus and a contractile vacuole, and each growing to the size of the original. A unit particle of protoplasm capable of carrying on the functions of life, namely, nutrition and reproduction, is termed a "cell." Formerly, a unit of this nature was supposed to be a sac or vesicle, hence the name "cell," which is retained, though many cells are solid and without a definite wall. The Protozoans are animals consisting of a single cell, or colonies of cells. In the latter case each cell is more or less independent of the others, and capable of carrying on all the functions of life. All animals above the Protozoa are composed of many cells united into a whole, in which there arises the principle of division of labour.

The Protozoa are divided into two groups, the Rhizopoda and the Infusoria; in the former the body-substance is of more or less uniform consistence, and can extend itself from any part of the surface in the form of pseudopods; whereas, in the latter, the outer layer is firmer and denser than the inner, and the animal has a more or less definite shape. In place of pseudopods, the Infusoria develop on their surface one or many fine processes in the shape of cilia or flagella, which set up food-carrying currents, converging towards a definite mouth, and which enable the animals to move rapidly about, when they are not fixed.

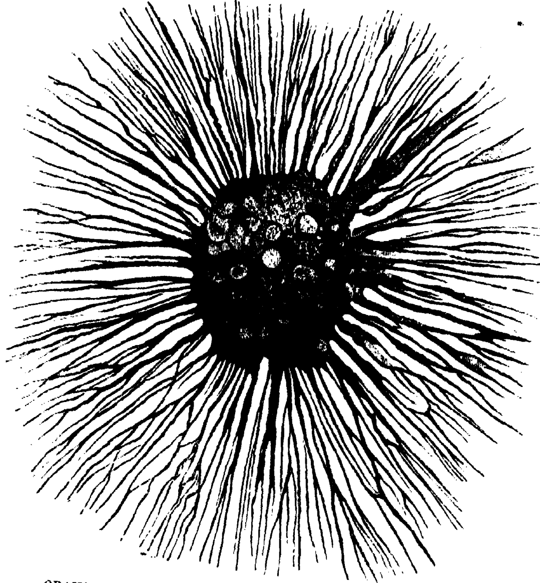
THE ROOT-FOOTED GROUP,—Class **Rhizopoda.**

The simple organisms of this class take their name from their power of protruding from the body the processes known as pseudopodia, which are often branched like roots of a tree, and by means of which they creep about. The group includes the amœbas, the foraminifers, the sun-animalcules, and radiolarians. In the first the pseudopodia are simple and lobose; in the second they are slender, confluent, and reticulate; while in the two last they are simple, radiating, and somewhat stiff.

THE AMŒBAS,—Order LOBOSA.

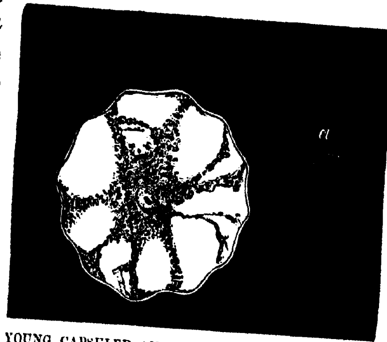
The chief character of this group consists in the usually broad lobose simple form of the pseudopods, which flow out from the body in the shape of finger-like processes. The simplest forms are apparently without even a nucleus, and on this account have been separated from the rest as the Monera. As the first representative of the group, we may take the form known as *Protomyxa*, which forms minute orange-coloured particles of jelly creeping over shells, and consists simply of protoplasm containing granules, oil-globules, and food-particles. Occasionally a specimen retracts all its pseudopodia, some of which are broad and others slender, and becomes a quiescent sphere, the contents of which break up into numerous portions, each of which forms a new individual. The amœbas are divided into two groups, the shell-less (Nuda), and the shelled forms (Testacea). The common amœba, which has been described above, belongs to the former group, as also does *Pelomyxa*, a large species found in the form of little white ovoid masses, about

the size of a pin's head, creeping on the mud of stagnant ponds; in this animal there is a definite fore-part and hind-part, the broader end of the ovoid mass being in front. The figure represents the capsuled animalcule (*Arcella*), common in pools, especially where there is bog-moss. The brown horny shell is marked



ORANGE-COLOURED PROTOMYXA (magnified 140 diameters).

with a finely faceted pattern, and is shaped like a dome with a flat floor; in the centre of the floor is a circular hole, through which short lobose pseudopods emerge from the body in the interior of the dome-like box. *Arcella* is capable of secreting vesicles of air in its body-substance, whereby it is enabled to rise. In *Euglypha* the shell is sac-shaped, with a jagged free margin, and the surface covered with regular overlapping scales. In *Difflugia* the shell is strengthened by the addition of foreign particles. Amœbas are cosmopolitan; occurring in sea and in fresh water, and a few living in mosses or damp earth. Certain forms of dysentery are said to be due to amœbas, or at least to amœba-like phases in the life-history of other Protozoa.

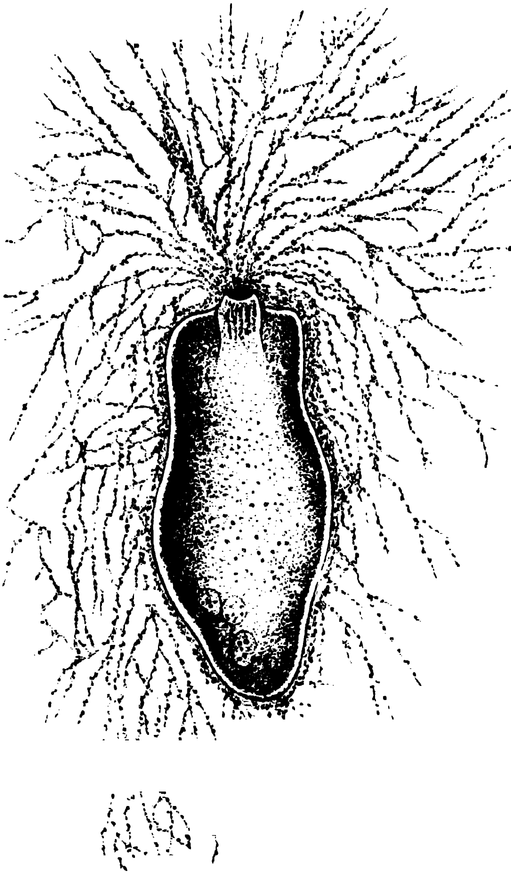


YOUNG CAPSULED ANIMALCULE, SEEN FROM ABOVE (magnified). *a*, Fragment of Shell (magnified 600 diameters).

The fungus-animals (Mycetozoa), are claimed both by botanists and zoologists. The best known species is the flowers of tan, found in tan-yards, in the form of large creeping masses of naked protoplasm, known as plasmodia. Cakes of protoplasm become segregated from the main mass, and break up into amœba-like spores, which again fuse to form plasmodia.

Order FORAMINIFERA.

If shelly sea-sand be looked over with a lens, there will often be seen tiny shells no bigger than the grains of sand amongst which they lie. The specimen illustrated on p. 558, and whose shell is about one-twentieth of an inch in diameter, was originally named the spiral nautilus, with crenated joints. Another kind (*Miliolina*) occurs in the shape of porcelain-like oval shells, one-twentieth of an inch in length, with about five visible segments, arranged somewhat like a string of sausages wound round each other not quite in the same plane. Foraminifera are rhizopods whose simple sarcode-bodies emit slender branching pseudopods, and which form a shell of membrane, of foreign particles of sand, etc., of carbonate of lime, or, in rare instances, of silica. The order is divided into two groups, the Imperforata and the Perforata; in the former of which the shell possesses only one or a few comparatively large apertures, whereas in the latter, in addition to its main opening, the shell has its walls perforated all over with small pores through which pseudopods can be emitted.



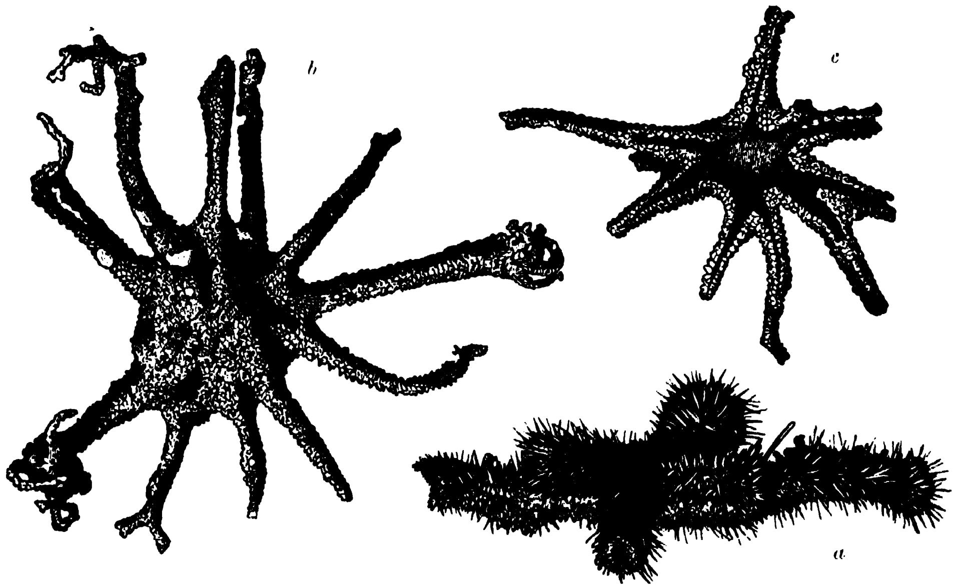
-SHAPED GROMIA, *Gromia oviformis* (magnified 600 diameter

The Imperforata form shells of membrane, agglutinated particles of sand, mud, sponge-spicules, etc., or of carbonate of lime; the vast majority of the Perforata form shells of the last-named material. The imperforate shells of carbonate of lime often resemble milk-white porcelain; whereas the perforate shells, especially in early stages, have a glassy appearance.

Gromia is found both in fresh and brackish water and in the sea in the form of minute, oval, egg-shaped bodies about one-twentieth of an inch in length, fixed on tufts of corallines, or loose in the sand and mud. At first there appears to be nothing remarkable about the tiny oval mass resembling the egg of a zoophyte; but presently from the opening at one end of the membranous sac or shell granular threads of sarcode creep out and become fixed on the glass slide; slender trunks of sarcode extend themselves, and divide into finer and finer branches, which reunite to form a network of streaming granular filaments ever changing in form, and which may extend to six or eight

times the length of the body. Every fibre exhibits an up and down stream of granules suspended in clear hyaline sarcode. A diatom, infusorian, or other edible prey, coming in contact with the pseudopods, is covered with a mass of protoplasm formed by fusion of several filaments, drawn down to the mouth of the shell and engulfed. *Gromia* moves by means of its pseudopods, which fix themselves and draw the body along. When alarmed, the animal withdraws into its membranous test.

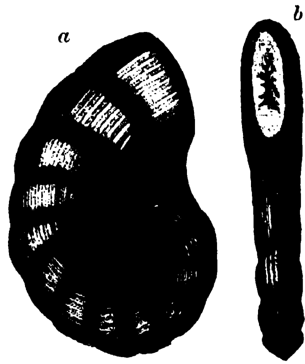
The sandy Foraminifera, which are mostly deep-sea types, are composed of masses of sarcode, sometimes of considerable size, which form shells or cases of agglutinated mud, sand-particles, or sponge-spicules. They frequently attain a



a Hyperammina ramosa ; *b* and *c*, *Astrorhiza limicola* ; *b*, Entire ; *c*, Cut open.

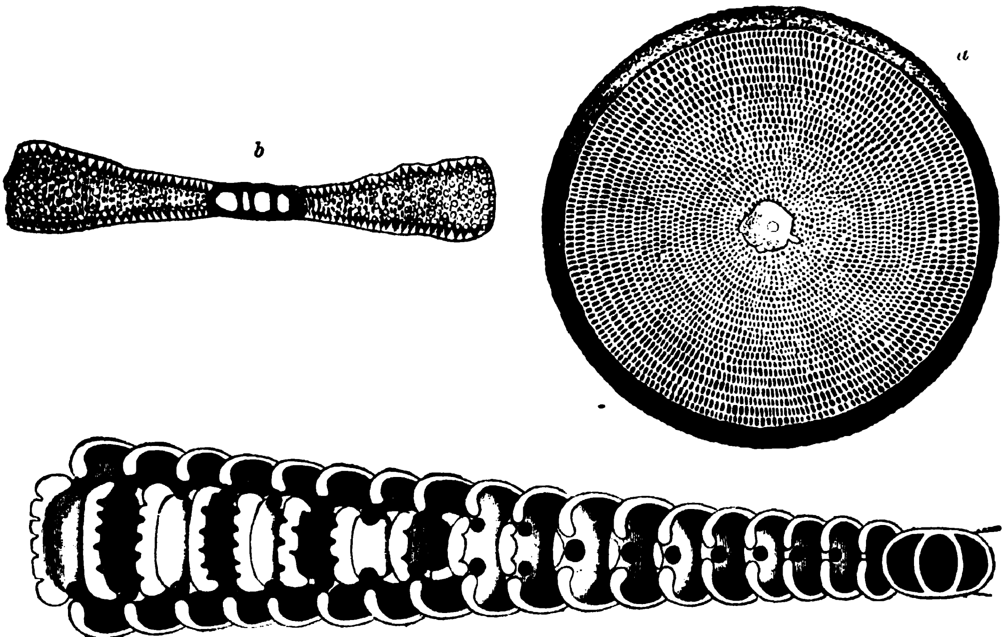
large size; for instance, *Bathysiphon*, from the Atlantic and also from fourteen hundred and twenty-five fathoms off Amboyna, forms a slender annulated tube, two inches in length, and open at each end, the walls of the tube being composed of cemented sponge-spicules. *Haliphysema* is found in shallow water in the North Atlantic in the form of minute club-shaped bodies, one-twentieth of an inch in height, with the narrowed lower end attached by a disc to zoophytes, etc., and with the surface bristling with sponge-spicules. *Hyperammina*, generally distributed in from sixty to three thousand fathoms, makes a test of cemented sand-grains and sponge-spicules, at first forming a globular chamber with a long branched neck, the branches of which again branch. *Astrorhiza* forms stellate single-chambered shells of fine mud, slightly cemented, and lined inside by a smooth membrane; at the ends of the arms are large openings for the pseudopods; the diameter of the disc is about one-fifth of an inch, and that of the entire shell about half an inch; the animal lives in comparatively shallow water (about twenty fathoms), in the North Atlantic. Certain other sandy species are characterised by the regular form of their shells, which resemble those of calcareous species. The imperforate calcareous species are usually milk-white. The shell possesses only one or a few

apertures. The seedlet miliolina, previously referred to, is one of the commonest species; it has a world-wide distribution from the shore to three thousand fathoms. The terminal opening of the last and largest segment is guarded by a branched tongue-like process. The Miliolite Limestone of the Paris Basin is composed almost entirely of the shells of *Miliolina* and other Foraminifera. A considerable part of Paris is built of this stone, in which the tiny miliolinas can be distinctly seen with the aid of a lens. The porcellaneous *Peneroplis* forms a spiral, with a slit in the last-formed segment, through which the protoplasm of the body can be extruded.



Peneroplis pertusus. *a*, Lateral view; *b*, Front view. (Magnified.)

Orbitolites, one of the Imperforata, forms discs from one to two inches in diameter. The shell is composed of a central coiled chamber, followed by concentric circles of chambers, the pores for the emission of pseudopods being situated on the edge of the disc. The different species of *Orbitolites* form an interesting series, illustrating transitions from a simple to the most complex type. In a vertical section of the disc of the figured species the innermost chambers exhibit the simple type, later formed ones the intermediate, and the outermost series the highest type and the greatest differentiation of structure.

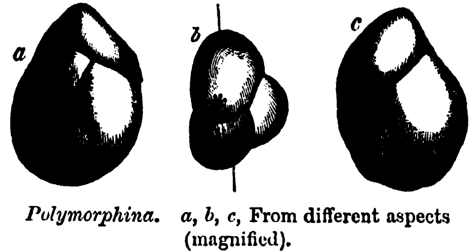


Orbitolites. *a*, From above; *b*, Transverse section (nat. size); *c*, Diagrammatic figure of section of *Orbitolites complanatus*, illustrating the transition from the simplest to the most complex type of structure.

The shells of the perforate Foraminifera may be constructed of only one, but most commonly of many, chambers, arranged according to various plans. The simplest type with one chamber (*Lagena*) is shaped like a Florence oil-flask; in many-chambered forms the segments may succeed one another in a

straight line or in a spiral, and the coils of the spiral may or may not be in the same plane; or, again, the segments may form alternately on each side of a long axis.

In *Polymorphina communis* the segments are combined in a somewhat obscurely spiral arrangement. In the Foraminifera group a number of forms have arisen exhibiting an extensive series of variations on a few simple types, and showing transitions between forms which at first seemed distinct. The majority of species live at the bottom of the sea, but some are pelagic, and occur in abundance on the surface. Among the latter, *Globigerina* is one of the most widely distributed. Its shell is about one-fortieth of an inch in diameter, and usually composed of seven globular chambers, arranged spirally in such a manner that all are visible from above, but only the last four from below. Each chamber opens by a crescentic orifice into the depression in the middle of the lower surface. Perfect specimens bristle with long slender spines. The pores afford passage to the pseudopods which stream along the spines. In life, the shell is sunk in the midst of a bubbly sphere of protoplasm, which serves as a float. The investigations of deep-sea expeditions have brought to light the fact that the floor of the ocean, at depths between five hundred and two thousand five hundred fathoms over vast areas, between 110° north and south of the Equator, is formed of a pinkish white mud, containing on an average about 60 per cent. of carbonate of lime. The presence of this material is mainly due to shells of Foraminifera, especially *Globigerinidæ*, and, to a small extent, to the remains of minute pelagic algæ, known as coccospheres and rhabdospheres; the broken fragments of the latter in the shape of discs and rods being termed coccoliths and rhabdoliths. Over the greater part of the floor of the Atlantic, and over immense tracts in the Western Indian Ocean and Pacific, over areas comprising in all about fifty millions of square miles, the ocean-bed is formed of Globigerina ooze. Chalk is mainly composed of the skeletons of *Globigerinidæ*, coccoliths, etc., and, in fact, resembles Globigerina ooze.



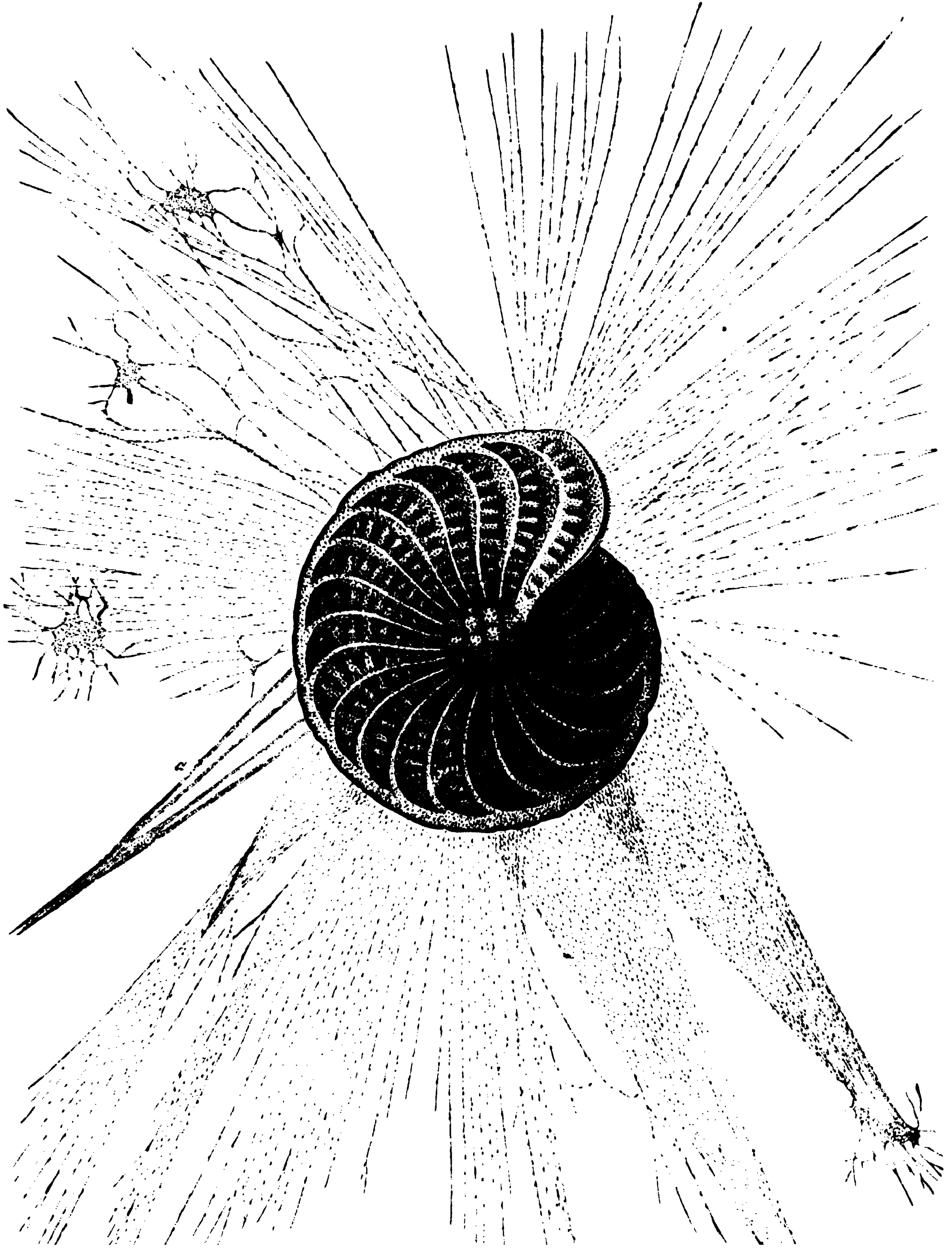
Polymorphina. *a, b, c*, From different aspects (magnified).



SHELLS OF *Globigerina* (much magnified).

The question whether the *Globigerinidæ*, which make up the bulk of the

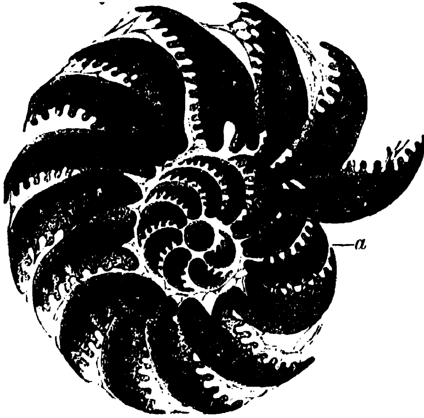
ooze, live at the bottom as well as at the surface, has given rise to much discussion. Dr. Murray has come to the conclusion that pelagic species do not live near



Polystomella (magnified 200 diameters).

the ocean floor. His opinion is partly based on the fact that the area of Globigerina ooze coincides with the area of surface temperature at which Globigerinas

are found to exist. When the surface water is too cold for surface Globigerinas, no Globigerina ooze is found below. Numerous species of Foraminifera, which live only at the bottom, and are never found at the surface, contribute a small percentage to the composition of the ooze, the bulk of which is, however, formed of organisms which have rained down from the surface. The deposits occurring in depths over two thousand five hundred fathoms do not contain calcareous matter. The rain of Foraminifera skeletons falls down from the surface as over the areas of lesser depth, but the shells are dissolved before they reach the bottom, apparently by the excess of carbonic acid in the deep zones of the ocean. Here the ooze is formed of red clay,—a material probably resulting from the disintegration of volcanic remains, pumice, etc., and almost devoid of organic traces. This deposit extends in its more or less unmixed condition over an area of about fifty-two millions of square miles, and is also present in varying proportions in Globigerina and other oozes. In from three to four thousand fathoms in the Eastern Indian Ocean and in part of the Central Pacific, over a total area of about two and a quarter millions of square miles, the deposit contains a large percentage of siliceous skeletons of Radiolaria, and is termed Radiolarian ooze. Beyond the northern and southern boundaries of the Globigerina ooze, in the Arctic and Antarctic Oceans the deposit consists of a fine, white, chalky-looking siliceous mud, with a green tinge in the shallower depths, mainly composed of the frustules of Diatoms.



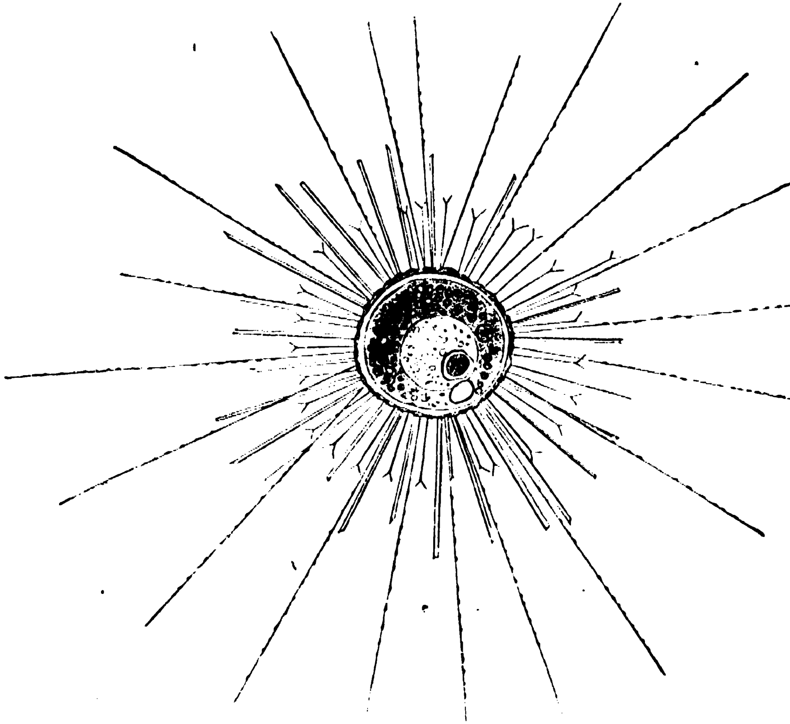
SARCODE BODY OF *Polystomella* AFTER SHELL HAS BEEN DISSOLVED IN ACID. *a*, Nucleus (200 diameters).

The figured *Polystomella*, which belongs to the Nummulite group (so named because some of the species resemble coin-like discs), is cosmopolitan, ranging from the shore-zone to abyssal depths. Only the last convolution of the spiral series of chambers is visible, a section of the shell revealing one or two more coils completely invested by the outer; the radiating lines mark the divisions of the chambers, and on the last partition of the last chamber is seen a series of minute pores. The second figure shows the sarcode-body of a nearly related species, whose shell has been dissolved by acid; the nucleus (*a*) being visible in one of the segments. Nummulitic limestones which cover an immense tract, extending from the Pyrenees, along Southern Europe and North Africa, through Asia Minor to the Himalaya, are composed of the shells of an allied genus (*Nummulites*). As these rocks belong to the Tertiary epoch, and form some of the highest Himalayan peaks, they indicate how recently these mountains have been elevated.

SUN-ANIMALCULES,—Order HELIOZOA.

These animalcules are inhabitants of fresh water; their chief characteristic, and the one to which they owe their name, being the possession of long, slender, somewhat stiff pseudopods, which radiate from all parts of the spherical

body, like sun-rays, as represented in pictures. The common sun-animalcule (*Actinophrys*) forms a tiny translucent spherical globule, bristling with pseudopods, and about $\frac{1}{250}$ of an inch in diameter. The pseudopods appear stiff but are quite flexible, and the body contains several clear vesicles, one of which is usually half emerged from the body and on the point of bursting; the nucleus being in the centre of the body. The animal can move over a hard surface by the alternate relaxation and stiffening of its pseudopods, and sometimes so quickly that it appears to run like a spider. When a pseudopod touches some small organism, the latter seems to become paralysed, the pseudopod approximating itself and its prey to the body, which sends up a

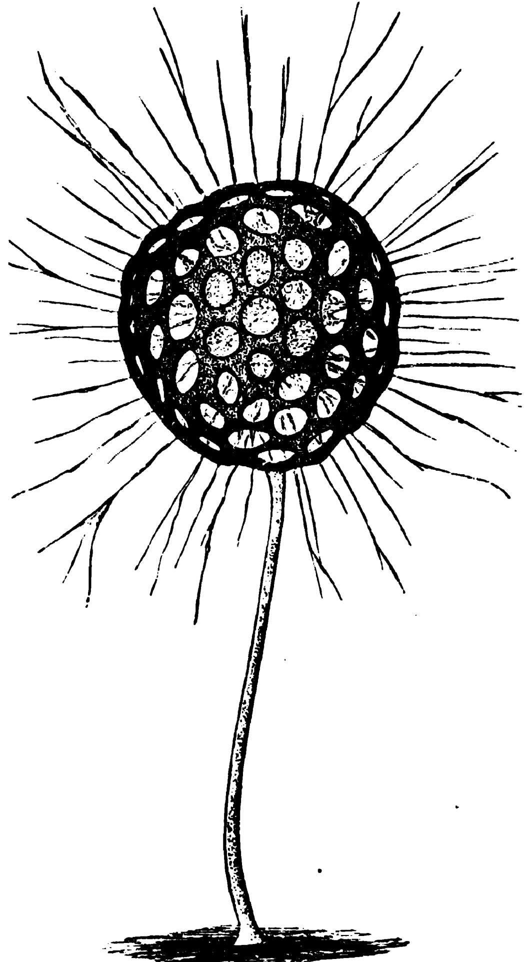


GREEN SUN-ANIMALCULE, *Acanthocystis chætophora* (highly magnified).

lobe wherein the organism is enveloped. Reproduction commonly takes place by simple division of the animal into two. The common sun-animalcule occurs abundantly amongst the weeds in clear pond-water. The green sun-animalcule (*Acanthocystis*) figured above is provided with a skeleton composed of fine siliceous rods or rays, the inner ends of which, buried in the body, are tipped with little discs, the outer ends being either simple or forked.

In another species the siliceous needles are arranged tangentially; further, the skeleton may be formed of a siliceous latticed sphere, as in the lattice-animalcule (*Clathrulina*), which grows fixed to aquatic plants by the base of its long flexible stalk. The body sends its long slender pseudopods through the meshes of the lattice; the total length of the animal is about $\frac{1}{200}$ of an inch.

Sun-animalcules often form colonies which result from the buds or the products of division remaining in contact and partly attached. The most likely places to find sun-animalcules are pools in the woods, where the bottom is covered with dead leaves, and among aquatic plants in ponds.


LATTICE-ANIMALCULE, *Clathrulina* (magnified 350 diameters).

Order RADIOLARIA.

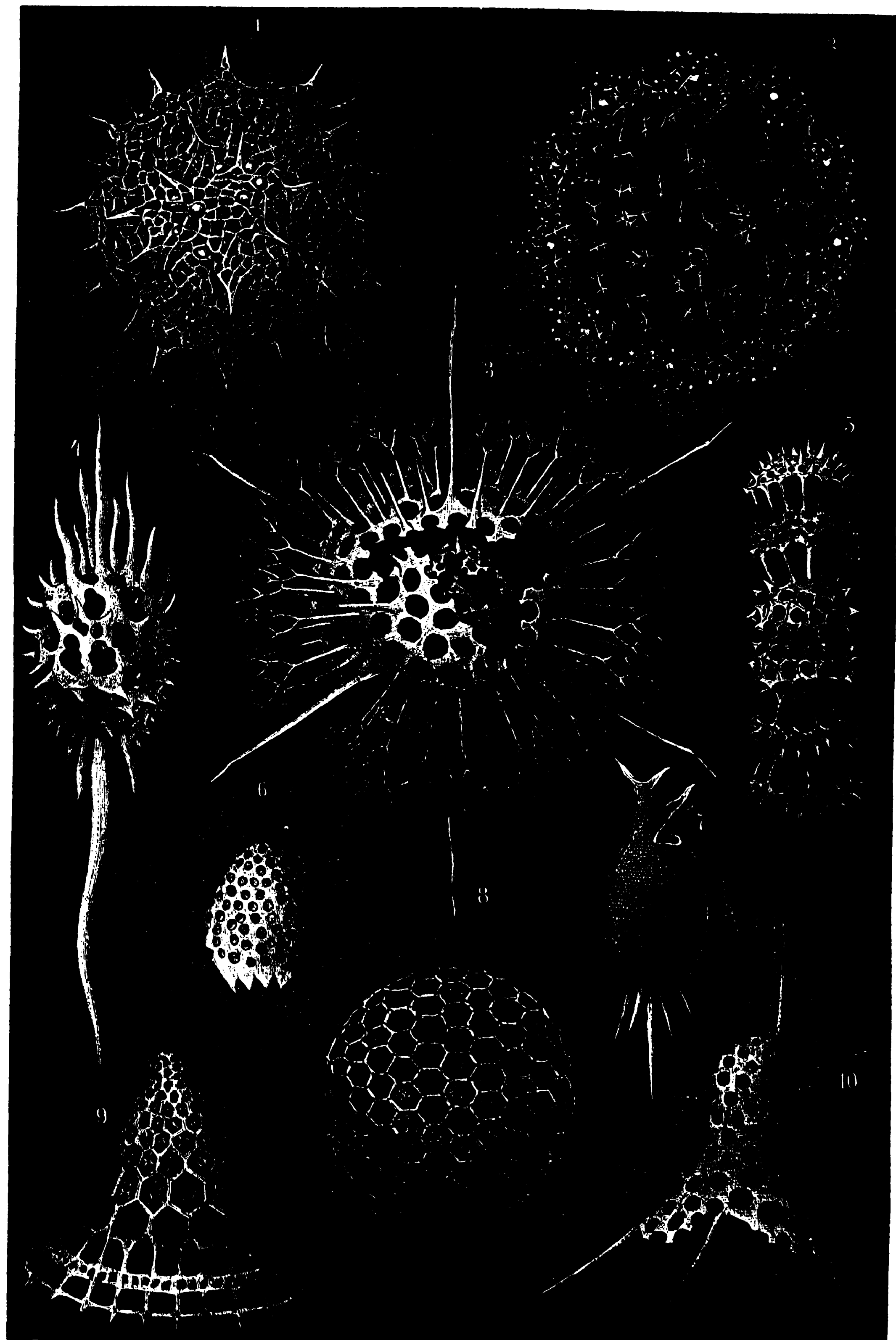
Both alive and in the form of their skeletons many of the radiolarians are surpassingly beautiful. Floating on the surface of the ocean, their tiny spheres or pyramids of translucent jelly glow with rich tints of crimson, blue, or yellow. They are all marine, and live in zones from the surface to several thousand fathoms. Many of the surface forms avoid a strong light, and only appear after sunset. Certain species which live in depths below one hundred fathoms, and whose bodies contain a dark green or black pigment, are probably phosphorescent Radiolarians are usually known by the flinty skeletons formed by many of them; yet it is not this feature which separates them from the other orders of rhizopods, but the possession of a membranous central capsule in the centre of the body and surrounding the nucleus. The body-substance outside the capsule is highly vacuolated in many species, and especially in surface forms. A few are without a skeleton, and consist of small spherical or oval masses of soft gluey protoplasm, with slender radiating pseudopods, and one or several central capsules; the presence of more than one of the latter indicating a colonial form of growth. In a few species the skeleton is formed of a glassy-looking horny substance, termed acanthin, arranged in the form of radiating spines.

The vast majority of species secrete a siliceous skeleton which assumes an endless variety of forms, such as trellis-work spheres, concentric spheres or boxes joined by radiating spines, helmets, baskets, lanterns, bee-hives, discs, rings, etc. Haeckel has described over four thousand species, and possibly as many more could be added to this number. Radiolaria are divided into two groups; in the first of these there is either no skeleton or one of silex, while in the second the skeleton

is formed of radiating spines of a horny nature. The first group is subdivided into three sections, according to the characters of the central capsule. In the first section the capsule is spherical and uniformly perforated by numerous small pores; in the second conical, with a perforated sieve-like floor area below; and in the third it has one main aperture and one or a few accessory ones, and is surrounded by a dark pigment. In the forms with a siliceous skeleton the geometrical pattern of the skeleton conforms more or less to the shape of the central capsule, being either spherical or conical. The central capsule is regarded as being homologous with the calcareous shell of Globigerina. Reproduction takes place by simple division into two, or by the breaking up of the body-substance into oval spores, each provided with a flagellum or whip. Two spores, which may be of similar or of different size, fuse together; the resulting individual growing into an adult radiolarian. Certain yellow corpuscles present in the outer part of the body of surface radiolarians are unicellular parasitic algæ, which can be separated and cultivated independently of their host. The radiolarians live floating at all depths. Some forms are abyssal, living in depths of one thousand to two thousand five hundred fathoms. Over certain areas in the Central Pacific and the south-eastern part of the Indian Ocean the ooze forming the ocean-bed is chiefly made up of their skeletons, sometimes to an extent of eighty per cent. of the deposit, which has hence been termed radiolarian ooze. The chalky-looking rock, known as Barbados earth, a Tertiary formation, is composed almost entirely of skeletons of radiolarians. Somewhat similar deposits exist in the Nicobar Islands, in Greece, and in Sicily. Fig. 1 of the Plate shows the elegant lattice sphere of *Rhizosphæra*. Fig. 2 represents *Sphærozoum*, whose skeleton consists of loose spicules, arranged tangentially. *Actinomma* (Fig. 3) possesses three concentric lattice-spheres, joined by radiating spikes. Fig. 7 represents a deep-sea form (*Challengeria*), whose oval case is formed of a regular, very fine-meshed network. Fig. 8 depicts the elegant lattice-sphere of *Heliosphæra*; while *Lithomespilus*, *Ommatocampe*, and *Carpocanium* are shown in Figs 4, 5, and 6, and *Clathrocyclas* and *Dictyophimus* in Figs. 9 and 10.

THE INFUSORIAL ANIMALCULES,—Class **Infusoria.**

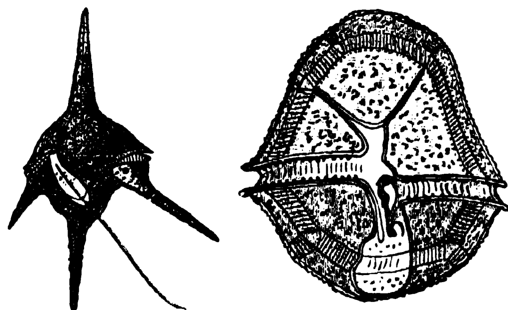
The name Infusoria, which came into use a hundred years ago, was applied to certain tiny living specks which appeared in infusions of hay, etc. The animalcules so named were classed with the worms and radiated animals, or zoophytes. As the microscope improved, infusorians were found to possess a considerable amount of structure. Ehrenberg attributed to them a highly complex organisation, supposing them to possess intestines, nervous system, etc. Later observations negatived these views, and showed them to be animals formed of one cell or composed of a colony of one-celled individuals. It is true that this cell, or unit-mass of protoplasm, may show a wonderful amount of differentiation, what with its nucleus, contractile vacuole, mouth and gullet, its variously arranged cilia or flagella, its contractile fibres, its separation into an outer denser and an inner more fluid protoplasm, and its horny cups, stalks, etc. Most of the species here described live in ponds and ditches, the larger forms preferring clear to stagnant and muddy water.



RADIOLARIANS.

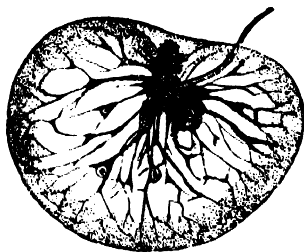
FLAGELLATED INFUSORIANS,—Order FLAGELLATA.

The characteristic of the group is the possession of one or two flagella, or small whip-like appendages, at the base of which is an opening in the denser surface-layer of protoplasm; a nucleus and contractile vacuoles are present, and frequently a brilliant red spot of pigment, known as the eye-spot. The Monads, which are the simplest members of the group, are common in fresh water and in infusions; typical forms consisting of a spherical or oval cell provided with a flagellum. Some species contain chlorophyll, and are claimed by the botanists. The common *Volvox*, for instance, which forms a green-coloured, spherical colony of monad cells has been described as a plant and also as an animal by botanists and zoologists respectively. The animal and vegetable kingdoms converge downwards towards a common point, at which it is difficult to say whether the manifestations of the physical basis of life—*i.e.* protoplasm—are such as we ascribe to plant life or to animal life. In the case of *Volvox*, the presence of chlorophyll would at first sight seem to stamp the organism as a plant; but the phases of life-history are rather those of an animal organism. The collared group possess cup-like collars, and they frequently secrete horny receptacles or cups, which may form elegant tree-like colonies.



MAIL-COATED FLAGELLATA (highly magnified).

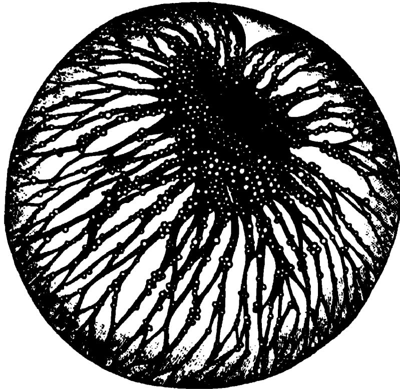
The mail-coated group are of very varied form, the body being often prolonged into long spiny processes. From the presence of cellulose in the cell-wall, and of chlorophyll in the body-substance, the proper position for these organisms would appear to be the vegetable kingdom, but taking their general life-history into consideration they may be regarded as animal organisms. They possess two large flagella which fit into grooves. *Ceratium tripos* (often looked upon as an alga), which sometimes forms chains of twenty or more individuals, is phosphorescent.



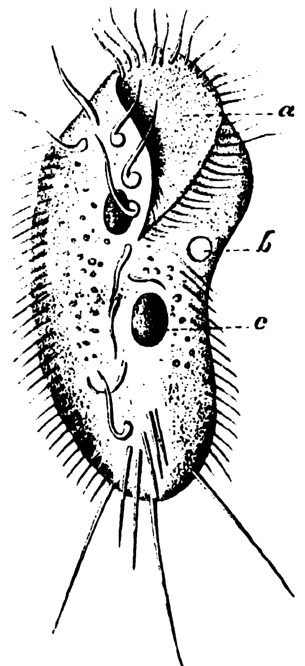
PHOSPHORESCENT ANIMALCULE, *Noctiluca* (magnified 150 diameters).

On calm dark nights during the summer and autumn the surface of the sea is occasionally seen to be pervaded by a beautiful bluish or greenish luminosity. The appearance of the phosphorescence is somewhat capricious, but it will best be seen on calm warm nights when there has been a gentle sea-breeze for several days. This strange phenomenon has attracted attention from the earliest times, but it was not till the middle of the last century that the cause was discovered. The luminosity is in most cases due to the presence of multitudes of tiny jelly-spheres, each smaller than a pin's head. On taking up a tumbler of the sea water, the spheres frequently form a thick layer at the surface. By separating a few of the organisms on blotting-paper, the light emitted will

enable one to see the time by a watch, at a distance of a foot or more. A few organisms swimming or floating about in plenty of sea-room in a tumbler of water, will not become luminous unless the water be shaken about, but when crowded together, they become diffusely luminous, owing to mutual jostling and irritation. The luminosity in an individual sphere, which should be inspected with a lens, may appear as a sudden, generally diffused flash, followed by darkness or by less intense light, or again, in the form of brilliant points of light. The name of the organism, which belongs to the flagellated infusorians, is *Noctiluca.* The body forms a peach-shaped cyst, about one-fiftieth of an inch in diameter, and with a tough membranous wall. A groove on the surface sinks at one end into a funnel leading into the interior. From the interior of the funnel there arises a large transversely striated flagellum, or proboscis, by means of which the animal swims, and there is also in the same place a fine whip-like flagellum. At the apex of the funnel there is a mass of sarcode, which extends itself as a wide-meshed, highly-vacuolated network, to the inner wall of the cyst, where it forms a thin layer, whence the phosphorescence emanates. *Noctiluca* multiplies by dividing into two, or by becoming encysted, after drawing in its flagella, and breaking up into numerous ciliated helmet-shaped "swarm-spores." Frequently two organisms fuse into one which may then divide up into spores. *Noctiluca* is found only in waters near land, the related forms met with in the open ocean belonging to the genus *Pyrocystis.* In one of the species of the latter the body is spherical, about one-thirtieth of an inch in diameter, and without the big flagellum. The phosphorescence, which in each individual chiefly emanates from the nucleus, is displayed on the ocean surface on calm nights in the Tropics. Prof. Butschli regards this species as an encysted or resting phase of the common form. *Noctiluca* occasionally swarms in such abundance as to give in daytime a reddish or yellowish hue to the surface. When the sea is rough, the organisms are dashed below the surface, and do not form a sufficiently continuous layer to give rise to much luminosity, and when the wind is off shore they are blown out to sea.



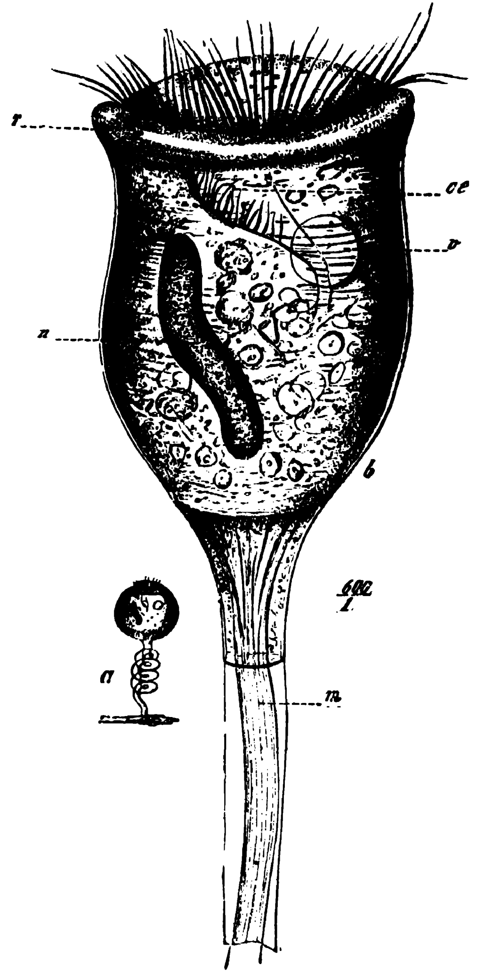
Pyrocystis (magnified 100 diameters).



MUSSEL-ANIMALCULE (*Stylonychia mytilus*) UNDER SURFACE.
a, Mouth ; *b*, Contractile vacuole ; *c*, Nucleus. (Magnified 150 diameters.)

Among the Flagellata are included certain parasitic organisms, which, owing to their being immersed in nutrient fluids, are not compelled to seek further for food, and do not possess flagella. The *Gregarina*, living in the intestine of the

lobster, is an elongated worm-like organism about two-thirds of an inch in length; it multiplies by becoming a spherical cyst, the contents of which break up into minute spore-like bodies with spindle-shaped cases, which are set free on the bursting of the cyst. Each of the spore-bodies also ruptures and liberates an amœba-like organism, which ultimately develops into an adult gregarina. Another species of gregarina lives in the intestines of the earth-worm. The Sporozoa are oval or spherical monad-like bodies, but without flagella, and live as parasites in the cells of plants and animals. Cancer and certain forms of malaria have been attributed to the presence of organisms of this nature in the fluids and tissues of the body.



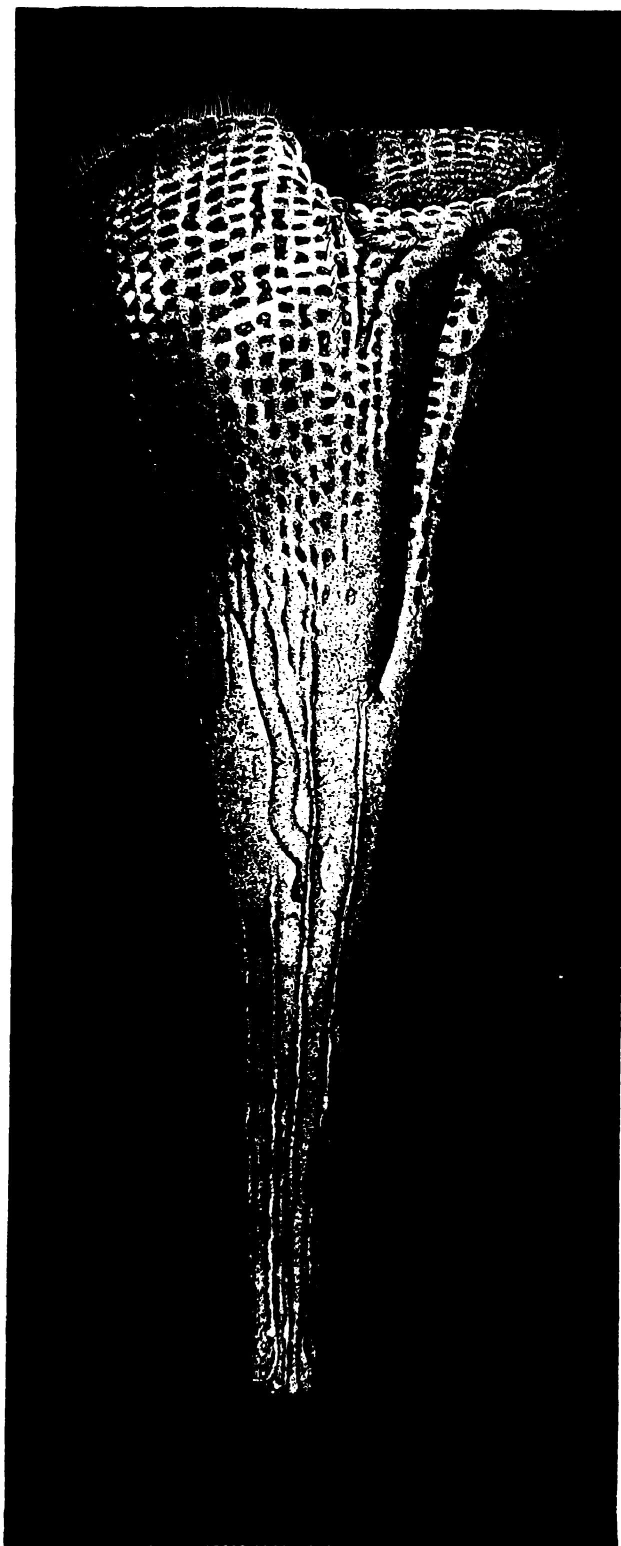
BELL-ANIMALCULE (*Vorticella*).
a, Slightly magnified; *b*, Magnified 600 diameters; *n*, Nucleus; *m*, Muscle-band.

Ciliated Infusoria,—Order Ciliata.


NODDING BELL-ANIMALCULE, *Epistylis* (nat. size = $\frac{1}{250}$ inch).

The organisms of this group are provided with cilia, limited either to the under side of the body, or forming a circle or spiral at one end, or arranged uniformly over the surface. Cilia are slender hair-like processes of the body, which move by bending and straightening themselves in unison; flagella are larger whip-like organs, and act more independently, the range of motion is not so restricted, and there are usually only one or two present on a cell. A few typical and common species are described.

The mussel-animalcule (*Stylonychia*), common in stagnant water, has the flattened oval body one-hundredth of an inch in length; on the under side is a ring of cilia, and at one end a funnel-shaped depression or mouth (*a*) with ciliated margin, leading through the dense outer protoplasm into the more fluid inner mass. The two dark oval bodies (*c*) are nuclei, and the clear spot (*b*) is the contractile vacuole which contracts rhythmically once in about every ten seconds. The creature can stalk along on the large bristle-like processes, in addition to swimming by means of its cilia; the


ROSEL'S TRUMPET-ANIMALCULE, *Stentor* (magnified 200 diameters).

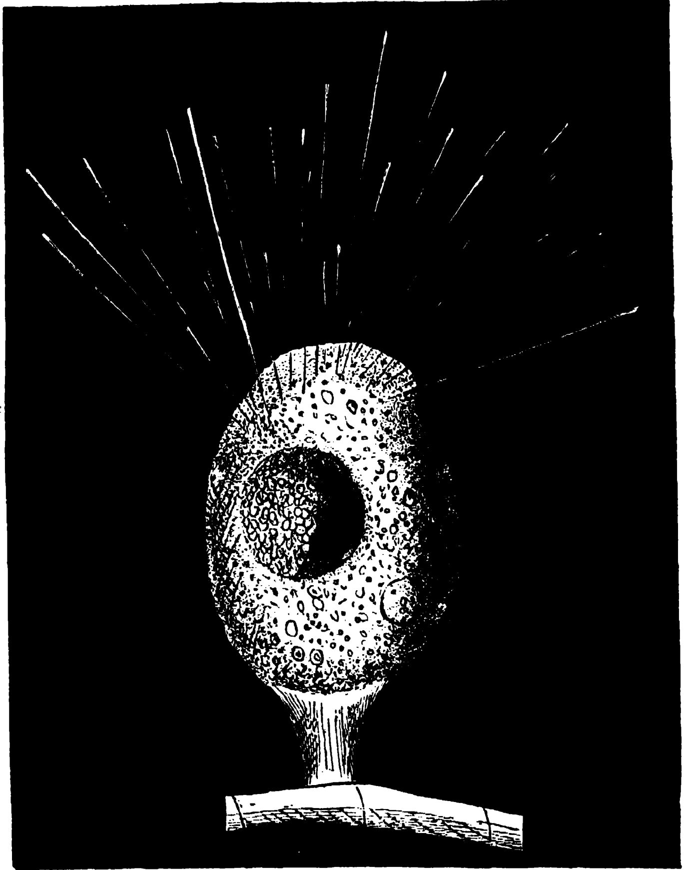
oral cilia set up currents which converge to the mouth-funnel, and carry in other infusoria, diatoms, etc.

The bell-animalcules usually possess stalks, and are either solitary or form branching colonies. *Vorticella*, whose outline is like that of a wine-glass, is provided at the rim with an incomplete circlet of cilia, one end of which passes down into the mouth-funnel at the margin (*r*) of the disc; the stalk contains a contractile band (*m*) which produces a rapid jerking motion by throwing the stem into coils; in the body-mass lie the nucleus (*n*) and contractile vacuole (*v*). Reproduction takes place by transverse division into two. Ehrenberg observed twelve individuals to originate from one within twenty-four hours, so that, calculating on this basis, one million individuals would be produced within twenty days. The common-branched bell-animalcule (*Carchesium*) divides more rapidly, namely, once in an hour; each again being soon ready for division, so that one thousand could arise in ten hours, and a million in twenty hours; but, as a matter of fact, only two hundred have actually been observed to have been formed in one day, owing to the intervals between successive divisions becoming longer. The vigour of the exhausted stock becomes rejuvenated, however, by the fusion or conjugation of two individuals into one.

The nodding bell-animalcule (*Epistylis*) forms little branching

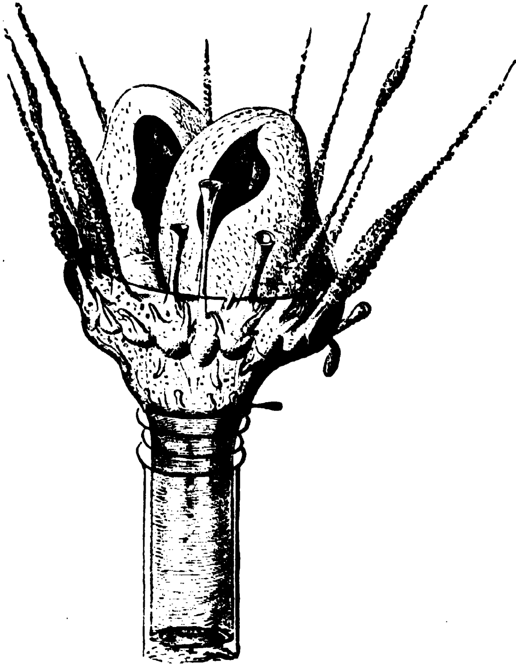
colonies growing on Conferva in stagnant water. When the animal is disturbed, the heads droop down towards the stalks. One of the forms most frequently met with is *Carchesium,* whose tiny branched tree-like colonies resemble moulds; but a few moments' inspection will undeceive the observer, for the little white globular stalked heads will be seen to be drawn down towards the base of the colony with a rapid jerking movement.

The trumpet-animalcule (*Stentor*) is of comparatively large size, being about one-twenty-fifth of an inch in length when extended. It is usually to be found fixed by its pointed end on the under side of duckweed Its form continually alters from a small knob when contracted, to a trumpet-shaped body when extended; and when in motion its shape continually changes, being in turn ovoid, pyriform, or even spherical. The surface is corrugated and covered with rows of cilia, by means of which the animal swims about. The long cilia at the upper part form a spiral, within the upper margin of which lies the mouth-slit. The mouth opens into a funnel, leading into the sarcode of the interior. The contractile vacuole lies to the right of the mouth-slit, and the nucleus forms an elongated beaded band along the length of the body. The ridge of cilia passing down vertically is the mouth-fringe of a new animalcule about to be formed by division. A cleft sinks in obliquely at one side of the ridge which assumes a wavy outline and later a spiral; the cleft sinks, till two complete animalcules are formed, with one-half of the nucleus, and a contractile vacuole in each. New individuals may also arise by the budding off of tiny ciliated embryos from the nucleus. The species of trumpet-animalcule most commonly met with is of a brilliant green colour; frequently clusters of them are found clinging by their pointed ends to the stem of a water-weed. A specimen has been cut into three parts, care being taken to leave a fragment of nucleus in each, with the result that each part has repaired itself into a complete animal; the central part, for instance, developing a head and a tail-end.



MARINE ANIMALCULE, *Acineta* (magnified 600 diameters).

The spiral-mouthed animalcules (*Spirostomum*) are among the largest of the class, and visible to the naked eye, especially in sunlight, as slender golden threads about one-tenth of an inch in length. The body is cylindrical, and the surface covered with rows of cilia; the mouth-slit extends along half the length of the under side, and is bordered on its left side by a fringe of long cilia. The animalcule is frequently twisted on its long axis, the mouth-cilia forming a spiral; multiplication takes place by transverse fission through the middle.



BUD-BEARING ANIMALCULE, *Hemiophrya* (highly magnified).

The curious marine animalcule *Acineta* is probably related to the ciliated infusorians. The stalked club-shaped body is usually fixed on sea-weeds or Bryozoa. From the upper end a number of straight sucker-like tentacles proceed; a nucleus and also clear vesicles are present in the body-substance; and the embryos are ciliated.

The bud-bearing *Hemiophrya* is also a marine-animalcule; it possesses a few suckers and a larger number of longer prehensile tentacles; on its margin several buds are formed, each containing a process of the nucleus, and the young forms when liberated are ciliated on their lower surface. The long tentacles capture and disable the prey, and bring it within reach of the suckers, which then surround and dissolve it, and finally appear to pump the newly-acquired nutriment into the general body-substance.

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SPIRAL-MOUTHED ANIMALCULE, *Spirostomum*. *a*, Nat. size.

